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IDENTIFIERS	*Electrical Wiring; Military Curriculum Project

ABSTRACT

This plan of instruction, lesson plans, workbooks, and study guides for a secondary-postsecondary course for electricians comprise one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. It contains the final three blocks of a five-block course (see note) intended to train students in electrical fundamentals, using tools and test equipment, installing service entrances, installing and performing maintenance on interior wiring systems in nonmetallic sheathed cable and conduit, motors and motor installation, and fire alarms, intrusion alarms, and cathodic protection systems. Block 3 (6 units) focuses on conduit wiring. The emphasis of Block 4 (5 units) is motors and controls. Block 5 (3 units) covers controls and alarm systems. The plan of instruction and lesson plans contain criterion objectives, an outline of instruction, teaching steps, activities, materials and tools needed, text assignments, and references. Contents of study guides include objectives, informative material, and study questions. Workbooks contain objectives, procedures, and study assignments. (YLB)

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Military Curriculum Materials for Vocational and Technical Education

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FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY
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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

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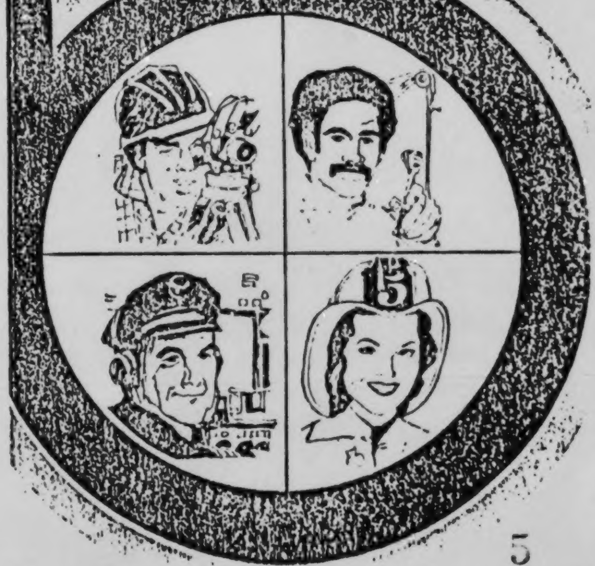
Information and Field Services Division

The National Center for Research in Vocational Education



Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
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WESTERN
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Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

ELECTRICIAN

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ELECTRICIAN Classroom Course 3-18

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Developed by:
United States Air Force

Development and Review Dates
May 1, 1975

D.O.T. No.:
824.281

Occupational Area:
Building and Construction

Target Audiences:
Grades 10-adult

Print Pages:
389

Cost:
$8.00

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials:	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction:	Group Instruction:	Individualized:
				No. of pages											
Block III															
Conduit Wiring		●		53		●	*		●	●	●	*		●	
Block IV															
Motors and Controls		●		43		●	*		●	●	●	*		●	
Block V															
Controls and Alarm System		●		10		●	*		●	●	●	*		●	

* Materials are recommended but not provided.

THE CENTER FOR VOCATIONAL EDUCATION

Expires July 1, 1978

Course Description

Electrician III, IV, and V contains the last three blocks of a five block course of study. Blocks I and II are included in a previous course, **Electrician I and II.** Training in this five-block course covers electrical fundamentals; using tools and test equipment; installing service entrances; installing and performing maintenance on interior wiring systems in nonmetallic sheathed cable and conduit; motors and motor installation; and fire alarms, intrusion alarms and cathodic protection systems. The first unit in Block III is not suitable for vocational education because it contains specific military materials and applications. The remaining sections in Blocks III, IV and V are suitable.

Block III – *Conduit Wiring*

Unit 2 – **Power Tools** (1 hour class instruction, 2 hours shop)
Unit 3 – **Conduit Tools, Terminology and Material** (2 hours class instructions, 1 hour shop)
Unit 4 – **Conduit Wiring** (7½ hours class instruction, 22½ hours shop, 8 hours study)
Unit 5 – **Low Voltage Circuits** (1 hour class instruction, 12 hours shop, 1 hour study)
Unit 6 – **Troubleshooting Conduit Circuits** (½ hour class instruction, 1½ hours shop, 1 hour study)
Unit 7 – **Appliance Maintenance** (1½ hours class instruction, 4½ hours shop, 2 hours study)

Block IV – *Motors and Controls*

Unit 1 – **Three-Phase Motor Systems** (11 hours class instruction, 13 hours shop, 8 hours study)
Unit 2 – **Troubleshooting Three-Phase Motor Systems** (1½ hours class instruction, 4½ hours shop, 2 hours study)
Unit 3 – **Single-Phase Motor Systems** (7 hours class instruction, 11 hours shop, 6 hours study)
Unit 4 – **Troubleshooting Single-Phase Motor Systems** (1½ hours class instruction 4½ hours shop, 2 hours study)
Unit 5 – **Motor Generators, Control Panels and Circuit Breakers** (3 hours class instruction, 1 hour shop, 2 hours study)

Block V – *Controls and Alarm Systems*

Unit 1 – – **Intrusion Alarm Systems** (12 hours class instruction, 6 hours shop)
Unit 2 – **Fire Alarm Systems** (4 hours class instruction, 4 hours shop)
Unit 3 – **Cathodic Protection and Corrosion Control** (2 hours class instruction)

Student materials include workbooks and study guides for each unit. Instructor materials include a plan of instruction for the course and lesson plans for each unit. Each block of instruction includes a measurement test and test critique.

III IV & V

3

PLAN OF INSTRUCTION
(Technical Training)

ELECTRICIAN

AIR TRAINING COMMAND

SHEPPARD TECHNICAL TRAINING CENTER

1 May 1975 - Effective 15 May 1975 with Class 750515

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LIST OF CURRENT PAGES

This POI consists of 46 current pages issued as follows:

Page No.	Issue
Title	Original
A	Original
i	Original
1 thru 40	Original
Annex (3 pages)	15 May 73

DISTRIBUTION: ATC/TTMS-1, AULD-1, SGPM-1, TCE-100, TTOT-1, TTOX-1, TTCR-1, TTE-1, CCAF/AY-2

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76-276

Pages 1 - 21 of this publication have been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." The deleted material is included in Electrician I & II (course 3-17).

PLAN OF INSTRUCTION	COURSE TITLE Electrician	
BLOCK TITLE Conduit Wiring		
UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
	6 (6/0) Day 21 (3/0)	Column 1 Reference — STS Reference 1a, 1b — 4f Instructional Materials SG AFS 54, 55, 56, Publications SG 3ABR54230-1-III-1, Publications
	(3/0)	WB 3ABR54230-1-III-1, Publications Air Force Publication Training File Audio Visual Aids Transparencies, Publications Training Equipment Project Cards (1) Technical Order File (1) Standard Publication File(1) Training Methods Discussion and Demonstration (2.5 hrs) Performance (3.5 hrs) Instructional Environment/Design Classroom (2.5 hrs) Laboratory (3.5 hrs) Group/Lockstep Instructional Guidance Explain the purpose and scope of technical order system and how to locate information using project cards, indexes and publications.

PLAN OF INSTRUCTION NO. 3ABR54230-1 DATE 1 May 1975 BLOCK NO. III PAGE NO. 21

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
2. Power Tools	3 (3/0) Day 22	Column 1 Reference: 2a, 2b, 2c STS Reference: 5a(2), 8o(4)
a. Given tools and equipment, index and drill holes in a piece of stock metal using a twist bit and drill press.	(1/0)	**Instructional Materials** SG 3ABR54230-1-III-2, Power Tools WB 3ABR54230-1-III-2, Power Tools
b. Given tools and equipment, dress the edges and corners of a piece of metal stock, using a bench grinder.	(1/0)	**Audio Visual Aids** Transparencies, Power Tools
c. Given tools and equipment, drill holes in a piece of stock metal using a portable drill.	(1/0)	**Training Equipment** Portable Power Drill (8) Drill Press (8) Bench Grinder (8) Hand Tool Set (8)
		Training Methods Discussion and Demonstration (1 hr) Performance (2 hrs)
		Instructional Environment/Design Classroom (1 hr) Laboratory (2 hrs) Group/Lockstep
		Instructional Guidance Review safety requirements for operation of power tools. Stress the necessity to ground all power equipment and to wear proper safety apparel when working with electrical equipment. Demonstrate the use of the equipment, then have the students complete the projects under close supervision.

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
3. Conduit Tools, Terminology and Material	3 (3/0) Day 22	**Column 1 Reference** 3a, 3b, 3c **STS Reference** 5a(1), 5a(4), 5a(5), 5a(6) **Instructional Materials** SG 3ABR54230-1-III-3, Conduit Tools, Terminology and Material WB 3ABR54230-1-III-3, Conduit Tools, Terminology and Material National Electrical Code **Audio Visual Aids** Transparencies, Tools, Terminology and Material **Training Equipment** Conduit Tools (8) Trainer, Conduit Demonstrator (8) Hand Tool Set (8) **Training Methods** Discussion and Demonstration (2 hrs) Performance (1 hr) **Instructional Environment/Design** Classroom (2 hrs) Laboratory (1 hr) Group/Lockstep **Instructional Guidance** Discuss and demonstrate various types of conduit tools, terminology and materials. Stress safety requirements when working with tools.
a. Given information pertaining to conduit tools, list the name and use of each tool.	(1/0)	
b. Given information pertaining to conduit terminology, list the definition of each term.	(1/0)	
c. Given information pertaining to conduit materials, list the name and use of the materials.	(1/0)	

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
4. Conduit Wiring	38 (30/8) Days 23,24 25,26,27	
a. Given information pertaining to conduit, complete statements in accordance with NEC specifications.	(1/0)	
b. Given a length of 1/2" rigid conduit, necessary tools and equipment, cut, ream, thread and bend the conduit to NEC specifications.	(5/0)	
c. Given a length of 1/2" EMT, necessary tools and equipment, cut, ream and bend the conduit to NEC specifications.	(4/1)	
d. Provided a booth area, hand tools and a working drawing, install a single-phase, 120/240 volt conduit service entrance and grounded panel board according to the NEC specifications.	(2/1)	
e. Provided a work area and necessary tools and equipment, install a ceiling light, single pole switch and duplex outlet in 1/2" EMT according to NEC specifications.	(6/2)	
f. Provided a work area, necessary tools and equipment, install a ceiling light controlled by two three-way switches according to NEC specifications.	(6/2)	

Column 1 Reference	STS Reference
4a	8e, 8f(1), 8f(2), 8f(3)
4b	5a(1), 5a(4), 5a(5), 8f(2)
4c	5a(1), 5a(4)
4d	8a(1), 8a(2), 8a(3), 8b, 8h, 8o(1), 8o(2)
4e, 4f, 4g	5a(1), 5a(4), 8d, 8e, 8f(1), 8f(2), 8f(3), 8i, 8m, 8o(1), 8o(2)
4h	5a(1), 5a(4), 8c, 8d, 8e, 8f(1), 8f(2), 8f(3)
4i	5a(1), 5a(4), 8f(1), 8f(2), 8f(3), 8m, 8o(1) 8o(2)

Instructional Materials
SG 3ABR54230-1-III-4, Conduit Wiring
WB 3ABR54230-1-III-4, Conduit Wiring
National Electrical Code
National Electrical Code and Blueprint Reading, K. L. Gebert

Audio Visual Aids
Transparencies, Switch Installation
Transparencies, Conduit Wiring

Training Equipment
Conduit Tools (8)
Hand Tool Set (8)
Vise, Pipe (4)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
g. Provided necessary tools and equipment and using the previously installed three-way switch system, add a four-way switch to control the light from three locations according to NEC specifications.	(2/0)	Training Methods Discussion and Demonstration (7.5 hrs) Performance (22.5 hrs) Outside Assignment (8 hrs)
h. Given a length of 3/4" EMT, a fused disconnect, tools and the necessary equipment, install conduit and feeder conductors between main panel and disconnect to meet NEC specifications.	(3/1)	Instructional Environment/Design Classroom (7.5 hrs) Laboratory (22.5 hrs) Study Hall (8 hrs) Group/Lockstep
i. Provided a work area, necessary tools and equipment, install a 220 volt receptacle in 3/4" EMT according to NEC specifications.	(1/1)	Instructional Guidance Discuss the different types of conduit and their uses according to the NEC. Explain how conduit sizes are determined. Discuss limiting factors on the number and minimum radius of bends. Demonstrate cutting, threading and bending procedures. Explain how to determine circuit requirements, wire size, color code, and conduit size. Explain and demonstrate the correct method to bend conduit. Stress safety. Check outside assignment daily. Assign students to read SG 3ABR54230-1-III-4, Conduit Wiring, and selected articles in NEC, chapter 4, on Conduit. Answer selected questions in NEC and Blueprint Reading, Gebert.
5. Circuit Extensions	4 (3/1) Day 28	Column 1 Reference — STS Reference 5a — 8k 5b — 8k, 8l, 8m, 8o(1) 5c — 8l
a. Given circuit extension information and a list of problems, find the answer to each problem.	(1/1)	Instructional Materials SG 3ABR54230-1-III-5, Circuit Extensions WB 3ABR54230-1-III-5, Circuit Extensions National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert
b. Provided a work area, necessary tools and equipment, install a circuit in surface metal raceway from an existing outlet, according to NEC specifications.	(1.5/0)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
c. Using previously installed circuits and meter, balance circuits according to NEC specifications.	(.5/0)	**Audio Visual Aids** Transparencies, Circuit Extensions **Training Equipment** Hand Tool Set (8) Multimeter, Clamp on Type, AN/USM-33 (4) **Training Methods** Discussion and Demonstration (1 hr) Performance (2 hrs) Outside Assignment (1 hr) **Instructional Environment/Design** Classroom (1 hr) Laboratory (2 hrs) Study Hall (1 hr) Group/Lockstep **Instructional Guidance** Discuss methods and use of circuit extensions. Demonstrate procedures for installation of surface metal raceway and NEC requirements. Stress safety. Have the students read SG 3ABR54230-1-III-5, Circuit Extensions, and selected articles in chapter 3, NEC, on Circuit Extensions. Answer selected questions in NEC Blueprint Reading, Gebert.
6. Low Voltage Circuits a. Provided a work area, tools and necessary equipment, install a low-voltage circuit according to NEC specifications.	3 (2/1) Day 28 (2/1)	**Column 1 Reference** 6a **STS Reference** 6f, 6i, 6o(1) **Instructional Materials** SG 3ABR54230-1-III-6, Low Voltage Circuits WB 3ABR54230-1-III-6, Low Voltage Circuits National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		Audio Visual Aids Transparencies, Installation of Low Voltage Circuits Training Equipment Hand Tool Set (8) Training Methods Discussion and Demonstration (.5 hr) Performance (1.5 hrs) Outside Assignment (1 hr) Instructional Environment/Design Classroom (.5 hr) Laboratory (1.5 hrs) Study Hall (1 hr) Group/Lockstep Instructional Guidance Explain the uses of low voltage systems. Discuss the purpose and operation of a step-down transformer. Discuss installation and maintenance of low voltage systems. Have students install a circuit containing a transformer, pushbutton and buzzer. Check outside assignment. Have students read SG 3ABR54230-1-III-6, Low Voltage Circuits and selected articles in chapter 7, NEC on Low Voltage Systems to answer selected questions in NEC Blueprint Reading, Gebert.

PLAN OF INSTRUCTION NO. 3ABR54230-1	DATE 1 May 1975	BLOCK NO. III	PAGE NO. 27

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)
7. Troubleshooting Conduit Circuits	10 (8/2) Days 28, 29 30
a. Provided a multimeter and instructions, troubleshoot an energized (120/240 volt) circuit to locate troubles inserted in the circuit by the instructor.	(3/1)
b. Provided a multimeter and instructions, troubleshoot a deenergized electrical circuit to locate troubles inserted by the instructor.	(3/1)
c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.	(2/0)

3 SUPPORT MATERIALS AND GUIDANCE

Column 1 Reference	STS Reference
7a, 7b	5b, 8o(1), 9m, 10a, 10b, 10c, 10e, 10f(1) 10f(2), 10f(3), 10g, 10h, 10i, 10k
7c	5a(1)

Instructional Materials

SG 3ABR54230-1-III-7, Troubleshooting Conduit Circuits
WB 3ABR54230-1-III-7, Troubleshooting Conduit Circuits
National Electrical Code
National Electrical Code and Blueprint Reading, K. L. Gebert

Audio Visual Aids

Transparencies, Troubleshooting

Training Equipment

Trainer, Conduit Troubleshooting Test Board (8)
Multimeter (1)
Hand Tool Set (8)

Training Methods

Discussion and Demonstration (1.5 hrs)
Performance (4.5 hrs)
Outside Assignment (2 hrs)

Instructional Environment/Design

Classroom (1.5 hrs)
Laboratory (4.5 hrs)
Study Hall (2 hrs)
Group/Lockstep

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Explain the methods and procedures for troubleshooting circuits. Discuss the various types of troubles and use of meters in locating circuit troubles. Using the circuits in the training booth, have the students locate and repair malfunctions. Check outside assignments daily. Have students read study guide 3ABR54230-1-III-8, Appliance Maintenance and selected articles in chapter 4, NEC on Appliances. Have students answer selected questions in NEC Blueprint Reading, Gebert.
8. Appliance Maintenance a. Given information pertaining to appliance maintenance, list the correct solution to each problem.	5 (3/2) Day 30 (3/2)	**Column 1 Reference** 8a **STS Reference** 9p **Instructional Materials** SG 3ABR54230-1-III-8, Appliance Maintenance WB 3ABR54230-1-III-8, Appliance Maintenance National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert **Audio Visual Aids** Transparencies, Appliances **Training Equipment** Trainer, Electrical Components (8) **Training Methods** Discussion and Demonstration (3 hrs) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (3 hrs) Study Hall (2 hrs) Group/Lockstep

PLAN OF INSTRUCTION NO 3ABR54230-1	DATE 1 May 1975	BLOCK NO. III	PAGE NO. 29

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Define an appliance. Discuss methods and procedures of identifying and correcting appliance troubles. Discuss the various parts of appliances and the problems with each. Check outside assignments daily. Have students read study guide 3ABR54230-1-III-8, Appliance Maintenance, selected articles in chapter 4, NEC, on appliances. Have students answer selected questions in NEC Blueprint Reading, Gebert.
9. Related Training	6	
10. Measurement Test and Test Critique	2/0 Day 30	

PLAN OF INSTRUCTION NO. 3ABR54230-1	DATE 1 May 1975	BLOCK NO. III	PAGE NO. 30

PLAN OF INSTRUCTION	COURSE TITLE Electrician	
BLOCK TITLE Motors and Controls		
UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Three-Phase Motor Systems	32 (24/8) Days 31,32 33, 34	**Column 1 Reference** — **STS Reference** 1a — 6i, 7b, 9d, 9g, 9f, 1b — 6i, 7b, 9d 1c, 1d — 7b, 9d 1e — 9d, 9f 1f, 1g, 1h, 1i — 9d, 9l **Instructional Materials** SG 3ABR54230-1-IV-1, Three-Phase Motor Systems WB 3ABR54230-1-IV-1, Three-Phase Motor Systems National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert **Audio Visual Aids** TF 1-5660a, Motor Connections TF 6082, Motor Controllers **Training Equipment** Trainer, Rotating Magnetic Field (8) Trainer, Motor and Motor Control (1) Trainer, AC Motor Installation Demonstrator (8) Trainer, Operation of Float Switch Control (8) Hand Tool Set (1) **Training Methods** Discussion and Demonstration (11 hrs) Performance (13 hrs) Outside Assignment (8 hrs)
a. Given the required information, select the equipment necessary to install a three-phase motor to power so the installation will meet NEC and manufacturer's specifications.	(6/2)	
b. Using a three-phase motor trainer and previously selected equipment, install and operate a three-phase motor on high voltage. Installation must meet NEC and manufacturer's specifications.	(2/1)	
c. Using a three-phase motor trainer and previously selected equipment, connect and operate a three-phase motor on low voltage. Installation must meet NEC and manufacturer's specifications.	(2/1)	
d. Using a three-phase motor trainer with previously installed three-phase motor, change power leads to reverse the direction of rotation to meet NEC and manufacturer's specifications.	(1/0)	

PLAN OF INSTRUCTION NO. 3ABR54230-1	DATE 1 May 1975	BLOCK NO. IV	PAGE NO. 31

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
e. Using a three-phase motor trainer, select an adequate motor overload protective device in accordance with the NEC, motor data plate and manufacturer's specifications.	(4/1)	Instructional Environment/Design Classroom (11 hrs) Laboratory (13 hrs) Study Hall (8 hrs) Group/Lockstep Instructional Guidance Discuss components and theory of operation of three-phase motors and controls. Discuss the NEC selection requirements of motors and controls based on the area in which the units will be located. Discuss data plate information, mechanical coupling to equipment and electrical installation. Trace and discuss schematics and wiring diagrams of motors and controls. Check outside assignments daily. Have students read selected sections of SG 3ABR54230-1-IV-1, Three-Phase Motor Systems, and selected articles in chapters 4 and 6 of NEC on Motors. Have students answer selected questions in NEC Blueprint Reading, Gebert.
f. Using a three-phase motor trainer, install a start/stop station to a three-phase magnetic controller to control a three-phase motor. Installation must meet NEC and manufacturer's specifications.	(3/1)	
g. Using a three-phase motor trainer, install two start/stop stations to a three-phase magnetic controller to control a three-phase motor. Installation must meet NEC and manufacturer's specifications.	(2/1)	
h. Using a three-phase motor trainer, install a thermostatic control to a three-phase magnetic controller to control the operation of a three-phase motor. Installation must meet NEC and manufacturer's specifications.	(2/0)	
i. Using a three-phase motor trainer, install a reversing start/stop station and a magnetic controller to control the direction of rotation of a three-phase motor in accordance with NEC and manufacturer's specifications.	(2/1)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)
2. Troubleshooting Three-Phase Motor Systems	8 (6/2) Day 35
a. Using a three-phase motor and trainer, inspect the motor installation in accordance with manufacturer's specifications.	(1/1)
b. Given a three-phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.	(4/1)
c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.	(1/0)

3 SUPPORT MATERIALS AND GUIDANCE

Column 1 Reference	STS Reference
2a	9a, 10a, 10d, 10g, 10j
2b	5a(1), 5b, 9e(1), 9i, 10e, 10f(1), 10f(2), 10f(3), 10f(4), 10h, 10j
2c	5a(1)

Instructional Materials
SG 3ABR54230-1-IV-2, Troubleshooting Three-Phase Motor Systems
WB 3ABR54230-1-IV-2, Troubleshooting Three-Phase Motor Systems
National Electrical Code
National Electrical Code and Blueprint Reading, K. L. Gebert

Training Equipment
Trainer, Motor and Motor Control (1)
Multimeter (1)
Megometer (4)
Hand Tool Set (1)

Training Methods
Discussion and Demonstration (1.5 hrs)
Performance (4.5 hrs)
Outside Assignment (2 hrs)

Instructional Environment/Design
Classroom (1.5 hrs)
Laboratory (4.5 hrs)
Study Hall (2 hrs)
Group/Lockstep

Instructional Guidance
Discuss conditions that cause malfunctions in motors and motor control systems. Explain the logical procedures for isolating troubles and correcting malfunctions. Put troubles into the installed motor system and have the students troubleshoot the system. Stress safety precautions. Check outside assignments daily. Have students read SG 3ABR54230-1-IV-2, Troubleshooting Three-Phase Motor Systems, answer questions at the end of the study guide and complete test 4A in NEC Blueprint Reading, Gebert.

PLAN OF INSTRUCTION (Continued)

<table>
<tr><th>1
UNITS OF INSTRUCTION AND CRITERION OBJECTIVES</th><th>2
DURATION (HOURS)</th><th>3
SUPPORT MATERIALS AND GUIDANCE</th></tr>
<tr><td>3. Single-Phase Motor Systems</td><td>24
(18/6)
Days 36, 37
38</td><td><table><tr><th>Column 1 Reference</th><th>STS Reference</th></tr><tr><td>3a</td><td>6i, 7b,</td></tr><tr><td>3b, 3c, 3d</td><td>6i, 9d</td></tr><tr><td>3e, 3f, 3g, 3h, 3i</td><td>6i, 7b, 9d, 9l</td></tr></table></td></tr>
<tr><td>a. Given the required information, select the equipment necessary to install a single-phase motor to a power source. Installation must meet NEC and manufacturer's specifications.</td><td>(6/2)</td><td>Instructional Materials
SG 3ABR54230-1-IV-3, Single-Phase Motor Systems
WB 3ABR54230-1-IV-3, Single-Phase Motor Systems
National Electrical Code
National Electrical Code and Blueprint Reading, K. L. Gebert</td></tr>
<tr><td>b. Using a single-phase motor trainer and previously selected equipment, install and operate a single-phase motor for low voltage operation. Installation must meet NEC and manufacturer's specifications.</td><td>(2/1)</td><td>Audio Visual Aids
TF 5660b, Single-Phase Motor Connections
TF 6180b, Motor Control System</td></tr>
<tr><td>c. Using a single-phase motor trainer and previously installed equipment, connect and operate a single-phase motor for high voltage operation. Installation must meet NEC and manufacturer's specifications.</td><td>(.5/0)</td><td>Training Equipment
Hand Tool Set (1)
Trainer, Motor and Motor Control (1)
Trainer, Electric Motor Exploded (8)</td></tr>
<tr><td>d. Using a single-phase motor trainer with previously installed single-phase motor, change motor leads to reverse the direction of rotation in accordance with NEC and manufacturer's specifications.</td><td>(.5/0)</td><td>Training Methods
Discussion and Demonstration (7 hrs)
Performance (11 hrs)
Outside Assignment (6 hrs)</td></tr>
<tr><td>e. Using a single-phase motor trainer, install a drum switch to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.</td><td>(3/1)</td><td>Instructional Environment/Design
Classroom (7 hrs)
Laboratory (11 hrs)
Study Hall (6 hrs)
Group/Lockstep</td></tr>
</table>

PLAN OF INSTRUCTION NO. 3ABR54230-1	DATE 1 May 1975	BLOCK NO. IV	PAGE NO. 34

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
2. **Troubleshooting Three-Phase Motor Systems**	8 (6/2) Day 35	Column 1 Reference STS Reference 2a 9a, 10a, 10d, 10g, 10j 2b 5a(1), 5b, 9e(1), 9i, 10e, 10f(1), 10f(2), 10f(3), 10f(4), 10h, 10j 2c 5a(1) Instructional Materials SG 3ABR54230-1-IV-2, Troubleshooting Three-Phase Motor Systems WB 3ABR54230-1-IV-2, Troubleshooting Three-Phase Motor Systems National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert Training Equipment Trainer, Motor and Motor Control (1) Multimeter (1) Megometer (4) Hand Tool Set (1) Training Methods Discussion and Demonstration (1.5 hrs) Performance (4.5 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (1.5 hrs) Laboratory (4.5 hrs) Study Hall (2 hrs) Group/Lockstep Instructional Guidance Discuss conditions that cause malfunctions in motors and motor control systems. Explain the logical procedures for isolating troubles and correcting malfunctions. Put troubles into the installed motor system and have the students troubleshoot the system. Stress safety precautions. Check outside assignments daily. Have students read SG 3ABR54230-1-IV-2, Troubleshooting Three-Phase Motor Systems, answer questions at the end of the study guide and complete test 4A in NEC Blueprint Reading, Gebert.
a. Using a three-phase motor and trainer, inspect the motor installation in accordance with manufacturer's specifications.	(1/1)	
b. Given a three-phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.	(4/1)	
c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.	(1/0)	

PLAN OF INSTRUCTION NO. 3ABR54230-1	DATE 1 May 1975	BLOCK NO. IV	PAGE NO. 33

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2
3. **Single-Phase Motor Systems**	24 (18/6) Days 36, 37 38
a. Given the required information, select the equipment necessary to install a single-phase motor to a power source. Installation must meet NEC and manufacturer's specifications.	(6/2)
b. Using a single-phase motor trainer and previously selected equipment, install and operate a single-phase motor for low voltage operation. Installation must meet NEC and manufacturer's specifications.	(2/1)
c. Using a single-phase motor trainer and previously installed equipment, connect and operate a single-phase motor for high voltage operation. Installation must meet NEC and manufacturer's specifications.	(.5/0)
d. Using a single-phase motor trainer with previously installed single-phase motor, change motor leads to reverse the direction of rotation in accordance with NEC and manufacturer's specifications.	(.5/0)
e. Using a single-phase motor trainer, install a drum switch to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.	(3/1)

SUPPORT MATERIALS AND GUIDANCE 3

Column 1 Reference	STS Reference
3a	6i, 7b,
3b, 3c, 3d	6i, 9d
3e, 3f, 3g, 3h, 3i	6i, 7b, 9d, 9l

Instructional Materials
SG 3ABR54230-1-IV-3, Single-Phase Motor Systems
WB 3ABR54230-1-IV-3, Single-Phase Motor Systems
National Electrical Code
National Electrical Code and Blueprint Reading, K. L. Gebert

Audio Visual Aids
TF 5660b, Single-Phase Motor Connections
TF 6180b, Motor Control System

Training Equipment
Hand Tool Set (1)
Trainer, Motor and Motor Control (1)
Trainer, Electric Motor Exploded (8)

Training Methods
Discussion and Demonstration (7 hrs)
Performance (11 hrs)
Outside Assignment (6 hrs)

Instructional Environment/Design
Classroom (7 hrs)
Laboratory (11 hrs)
Study Hall (6 hrs)
Group/Lockstep

PLAN OF INSTRUCTION NO. 3ABR54230-1	DATE 1May 1975	BLOCK NO. IV	PAGE NO. 34

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
f. Using a single-phase motor trainer, install one start/stop station to a single-phase magnetic controller to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.	(2/1)	Instructional Guidance Discuss components and theory of operation of single-phase motors and controls. Trace and discuss schematics and wiring diagrams of motors and controls. Discuss installation procedures and NEC requirements for motors and controls. Discuss the personnel safety and equipment care required in the operation and use of motors. Have students read selected sections of SG 3ABR54230-1-IV-3, Single Phase Motor Systems. Review selected articles in chapters 4 and 6 of the NEC and answer selected questions in NEC Blueprint Reading, Gebert.
g. Using a single-phase motor trainer, install two start/stop stations to a single-phase magnetic controller to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.	(1/0)	
h. Using a single-phase motor trainer, install a thermostatic control to previously installed magnetic controller to operate a single-phase motor system. Installation must meet NEC and manufacturer's specifications.	(1/0)	
i. Using a single-phase motor trainer, install a hand-off-automatic switch and thermostat to previously installed single-phase magnetic controller to operate a single-phase motor system. Installation must meet NEC and manufacturer's specifications.	(2/1)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
4. Troubleshooting Single-Phase Motor Systems	8 (6/2) Day 39	**Column 1 Reference** — **STS Reference** 4a — 9a, 10a, 10g, 10j 4b — 5a(1), 5b, 9e(1), 9i, 10e, 10f(1), 10f(2), 10f(3), 10f(4), 10h, 10j 4c — 5a(1) **Instructional Materials** SG 3ABR54230-1-IV-4, Troubleshooting Single-Phase Motor Systems WB 3ABR54230-1-IV-4, Troubleshooting Single-Phase Motor Systems National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert **Training Equipment** Trainer, Motor and Motor Control (1) Multimeter (1) Megohmmeter (4) Hand Tool Set (1) **Training Methods** Discussion and Demonstration (1.5 hrs) Performance (4.5 hrs) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (1.5 hrs) Laboratory (4.5 hrs) Study Hall (2 hrs) Group/Lockstep **Instructional Guidance** Discuss conditions that cause malfunctions in motors and motor control systems. Explain the logical procedures for isolating troubles and correcting malfunctions. Put troubles into the installed motor system and have the students troubleshoot the system. Stress safety precautions. Check outside assignment daily. Have students read SG 3 3ABR54230-1-IV-4, Troubleshooting Single Phase Motor Systems, answer the questions in the study guide and complete test 4B in NEC Blueprint Reading, Gebert.
a. Using a single-phase motor and trainer inspect the motor installation in accordance with manufacturer's and NEC specifications.	(1/1)	
b. Given a single-phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.	(4/1)	
c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.	(1/0)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
5. Motor Generators, Control Panels and Circuit Breakers.	6 (4/2) Day 40	Column 1 Reference: 5a, 5b STS Reference: 9k Instructional Materials SG 3ABR54230-1-IV-5, Motor Generators, Control Panels and Circuit Breakers WB 3ABR54230-1-IV-5, Motor Generators, Control Panels and Circuit Breakers National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert Training Equipment Trainer, Motor Control Center and Motor Generator Set (8) Trainer, Line Alternator Motor Control (8) Training Methods Discussion and Demonstration (3 hrs) Performance (1 hr) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (3 hrs) Laboratory (1 hr) Study Hall (2 hrs) Instructional Guidance Familiarize students with the components of the motor control panels and their purpose. Identify the purpose, components and operations of a motor generator set. Check outside assignment daily. Have students read SG 3ABR54230-1-IV-5, Motor Generators, Control Panels and Circuit Breakers, selected articles in chapter 7, NEC, answer selected questions in NEC Blueprint Reading, Gebert.
a. Using information provided, write the purpose of a motor control center and list its major components.	(2/1)	
b. Using information provided, write the purpose of a motor generator set and list its major components.	(2/1)	
6. Measurement Test and Test Critique	2/0 Day 40	

PLAN OF INSTRUCTION

COURSE TITLE
Electrician

BLOCK TITLE
Controls and Alarm Systems

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Intrusion Alarm Systems	18 (18/0) Days 41,42 and 43	Column 1 Reference — STS Reference 1a — 9o(3) 1b — 7a, 9o(3) Instructional Materials SG 3ABR54230-1-V-1, Intrusion Alarm Systems WB 3ABR54230-1-V-1, Intrusion Alarm Systems Audio Visual Aids Transparencies, Intrusion Alarm Systems Training Equipment Trainer, Intrusion Alarm (8) Multimeter (4) Training Methods Discussion and Demonstration (12 hrs) Performance (6 hrs) Instructional Environment/Design Classroom (12 hrs) Laboratory (6 hrs) Group/Lockstep Instructional Guidance Discuss the various types of intrusion alarm systems with students. Cover the theory of operation, terms and definitions. Trace wiring diagrams. Demonstrate operation of the intrusion alarm trainers. Students will inspect, service, troubleshoot and repair electrical components using meter.
a. Given information pertaining to intrusion alarm systems, inspect and service electrical systems and components.	(12/0)	
b. Using meter, trainer, and wiring diagram, troubleshoot and repair electrical systems and components of intrusion alarm systems.	(6/0)	

PLAN OF INSTRUCTION NO.	DATE	BLOCK NO.	PAGE NO.
3ABR54230-1	1 May 1975	V	38

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
2. Fire Alarm Systems	8 (8/0) Days 44, 45	Column 1 Reference — STS Reference 2a — 7a, 9o(3) 2b, 2c — 7a, 9o(3)
a. Given information pertaining to a fire alarm system, trainer and wiring diagram, identify components and trace electrical circuits.	(4/0)	Instructional Materials SG 3ABR54230-1-V-2, Fire Alarm Systems WB 3ABR54230-1-V-2, Fire Alarm Systems
b. Given fire alarm trainer, inspect and service electrical systems and components.	(1/0)	Audio Visual Aids Transparencies, Fire Alarm Systems
c. Given a fire alarm trainer and meter, troubleshoot and repair electrical systems and components.	(3/0)	Training Equipment Trainer, Fire Alarm Systems (8) Multimeter (2) Hand Tool Set (2) Training Methods Discussion and Demonstration (4 hrs) Performance (4 hrs) Instructional Environment/Design Classroom (4 hrs) Laboratory (4 hrs) Group/Lockstep Instructional Guidance Discuss types of fire alarm systems. Discuss theory of operation, terms and definitions. Trace wiring diagrams. Demonstrate operation of fire alarm trainer. Students will use wiring diagram to trace and troubleshoot electrical components of systems.

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
3. Cathodic Protection and Corrosion Control	2 (2/0)	**Column 1 Reference** — **STS Reference** 3a — 10k 3b — 9n Instructional Materials SG 3ABR54230-1-V-3, Cathodic Protection and Corrosion Control WB 3ABR54230-1-V-3, Cathodic Protection and Corrosion Control Training Equipment Trainer, Impressed Current Cathodic Protection System (8) Training Methods Discussion and Demonstration (2 hrs) Instructional Environment/Design Classroom (2 hrs) Group/Lockstep Instructional Guidance Discuss the effects of corrosion on metal. Introduce cathodic protection as a system to prevent or retard the deterioration of metal structures due to corrosion. Show impressed current system trainer to students.
a. Given information pertaining to corrosion, match correct terms with definitions.	Day 45 (1/0)	
b. Given information pertaining to cathodic protection, complete statements to identify methods of cathodic protection.	(1/0)	
4. Related Training	10	
5. Measurement Test and Test Critique	1/0 Day 45	
6. Course Critique and Graduation	1/0 Day 45	

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/26May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Power Tools (Day 22)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
3 Hrs	0	3 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
22	1 May 75	2

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	20 Dec 70 (14 Jan 72, 6 May 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Portable Power Drill Bench Grinder Hand Tool Set Projector, Overhead	None	None	SG III-2; WB III-2 Transparencies, Power Tools

CRITERION OBJECTIVES AND TEACHING STEPS

2a. Given tools and equipment, index and drill holes in a piece of stock metal using a twist bit and drill press.

- (1) Characteristics of a drill press
- (2) Operating procedures
- (3) Safety procedures for using a drill press

2b. Given tools and equipment, dress the edges and corners of a piece of metal stock using a bench grinder.

- (1) Characteristics of a bench grinder
- (2) Operating procedures
- (3) Safety precautions

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

2c. Given tools and equipment, drill holes in a piece of stock metal using a portable drill.

(1) Characteristics of portable drills
(2) Operating procedures
(3) Safety precautions

Course No: 3ABR54230-1
Day: 22

Branch Approval: Bobby D Littlejohn
Date: 26 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

Review subject matter covered in previous day or individual problem area.

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (2 Hours 45 Minutes)

PRESENTATION:

2a. Given tools and equipment, index and drill holes in a piece of stock metal, using a twist bit and drill press.

(1) Characteristics

(2) Operating procedures

(3) Safety procedures for using a drill press

2b. Given tools and equipment, dress the edges and corners of a piece of metal stock, using a bench grinder.

(1) Characteristics of a bench grinder

(2) Operating procedures

(3) Safety precautions

2c. Given tools and equipment, drill holes in a piece of stock metal using a portable drill.

(1) Characteristics of portable drills

(2) Operating procedures

(3) Safety precautions

APPLICATION:

WB 3ABR54230-1-III-2, Power Tools

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (First three hours Day 22)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

None

LESSON PLAN (Part I, General)

APPROVAL OFFICE/DATE TCETC/29May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Conduit Tools, Terminology and Material (Day 22)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
3 Hrs	0	3 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
23	1 May 75	3

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 73, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Conduit Tools Trainer, Conduit Demonstrator Hand Tool Set Projector, Overhead	None	None	SG III-3; WB III-3; National Electrical Code; Transparencies, Tools, Terminology and Materials

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Given information pertaining to conduit tools, list the name and use of each tool.

(1) Hand tools
(2) Power tools
(3) Correct use of tools
(4) Care of tools
(5) Safety while using tools

3b. Given information pertaining to conduit terminology, list the definition of each term.

(1) Conduit terms

35

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(2) NEC definitions

3c. Given information pertaining to conduit materials, list the names and uses of the materials

(1) Types of materials
(2) Uses of materials

Course No: 3ABR54230-1
Day: 22

Branch Approval: Bobby G Littlejohn
Date: 26 May 75

PART II

INTRODUCTION (5 Minutes)

ATTENTION:

REMOTIVATION:

OVERVIEW:

BODY (2 Hours 45 Minutes)

PRESENTATION:

3a. Given information pertaining to conduit tools, list the name and use of each tool.

(1) Hand tools

(2) Power tools

(3) Correct use of tools

(4) Care of tools

(5) Safety while using tools

3b. Given information pertaining to conduit terminology, list the definition of each term.

(1) Conduit terms

(2) NEC definitions

3c. Given information pertaining to conduit materials, list the name and use of the materials.

(1) Types of materials

(2) Uses of materials

APPLICATION:

WB 3ABR54230-1-III-3, Conduit Tools, Terminology and Materials

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (Day 22, 10 minutes)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-4, Conduit Wiring

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/29May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Conduit Wiring (Days 23 thru 27)

LESSON DURATION

CLASSROOM/LABORATORY 30 Hrs	COMPLEMENTARY 8 Hrs	TOTAL 38 Hrs

POI REFERENCE

PAGE NUMBER 24	PAGE DATE 1 May 75	PARAGRAPH 4

STS/CTS REFERENCE

NUMBER 542X0, Changes 1, 2, 3, 4, and 5	DATE 20 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Conduit Tools Hand Tool Set Vise, Pipe Projector, Overhead	None	None	SG III-4; WB III-4; NATIONAL ELECTRICAL CODE NATIONAL ELECTRICAL CODE AND BLUEPRINT READING TRANSPARENCIES, SWITCH INSTALLATION TRANSPARENCIES, CONDUIT WIRING

CRITERION OBJECTIVES AND TEACHING STEPS

4a. Given information pertaining to conduit, complete statements in accordance with NEC specifications.

(1) Installation requirements

(a) Article 215
(b) Article 346
(c) Article 348
(d) Article 350

(2) Forming conduit

(a) Types of bends

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(b) How to bend

4b. Given a length of 1/2" rigid conduit, necessary tools, and equipment, cut, ream, thread, and bend the conduit to NEC specifications.

(1) Cutting
(2) Reaming
(3) Threading

4c. Given a length of 1/2" EMT, necessary tools and equipment, cut, ream, and bend the conduit to NEC specifications.

(1) Cutting
(2) Reaming
(3) Threading

4d. Provided a booth area, hand tools and a working drawing, install a single-phase, 120/240 volt conduit service entrance and grounded panel board according to the NEC specifications.

(1) Forming conduit
(2) Panel installations
(3) Feeder conductors
(4) NEC requirements

4e. Provided a work area and necessary tools and equipment, install a ceiling light, single pole switch and duplex outlet in 1/2" EMT according to NEC specifications

(1) Installation methods
(2) Circuitry

4f. Provided a work area, necessary tools and equipment, install a ceiling light controlled by two three-way switches according to NEC specifications.

(1) Purpose of three-way switches
(2) Operation of three-way switches
(3) Circuitry

4g. Provided necessary tools and equipment and using the previously installed three-way switch system, add a four-way switch to control the light from three locations according to NEC specifications.

(1) Purpose of four-way switches
(2) Operation of four-way switches
(3) Circuitry

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

4h. Given a length of 3/4" EMT, a fused disconnect, tools and the necessary equipment, install conduit and feeder conductors between main panel and disconnect to meet NEC specifications.

(1) Purpose
(2) Circuitry

4i. Provided a work area, necessary tools and equipment, install a 220 volt receptacle in 3/4" EMT according to NEC specifications.

(1) Purpose
(2) Circuitry

Course No: 3ABR54230-1
Days: 23, 24, 25, 26 and 27

Branch Approval: Bobby S Littlejohn
Date: 26 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (24 Hours 45 Minutes)

PRESENTATION:

4a. Given information pertaining to conduit, complete statements in accordance with NEC specifications.

(1) Installation requirements

(a) Article 215

(b) Article 346

(c) Article 348

(d) Article 350

(2) Forming conduit

(a) Types of bends

(b) How to bend

4b. Given a length of 1/2" rigid conduit, necessary tools and equipment, cut ream, thread, and bend the conduit to NEC specifications.

(1) Cutting

(2) Reaming

(3) Threading

APPLICATION:

WB 3ABR54230-1-III-4, Conduit Wiring
Projects 1 and 2

CONCLUSION (Day 23)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-4, Conduit Wiring

INTRODUCTION (Day 24)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

4c. Given a length of 1/2" EMT, necessary tools and equipment, cut, ream, and bend the conduit to NEC specifications.

(1) Cutting

(2) Reaming

(3) Bending

4d. Provided a booth area, hand tools, and a working drawing, install a single-phase, 120/240 volt conduit service entrance and grounded panelboard according to the NEC specifications.

(1) Forming conduit

(2) Panel installation

(3) Feeder conductors

(4) NEC requirements

APPLICATION:

WB 3ABR54230-1-III-4, Conduit Wiring Projects 3 and 4 (EMT Forming and Service Entrance)

CONCLUSION (Day 24)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-4, Conduit Wiring (Conduit Installations)

INTRODUCTION (Day 25)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

4e. Provided a work area and necessary tools and equipment, install a ceiling light, single pole switch and duplex outlet in 1/2" EMT according to NEC specifications.

(1) Installation methods

(2) Circuitry

APPLICATION:

WB 3ABR54230-1-III-4, Conduit Wiring,
Project 5

CONCLUSION (Day 25)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-4, Conduit Wiring

INTRODUCTION (Day 26)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

4f. Provided a work area, necessary tools and equipment, install a ceiling light controlled by two three-way switches according to NEC specifications.

(1) Purpose of three-way switches

(2) Operation of three-way switches

(3) Circuitry

APPLICATION:

WB 3ABR54230-1-III-4, Conduit Wiring, Project 6

CONCLUSION (Day 26)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1, Conduit Wiring

INTRODUCTION (Day 27)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

4g. Provided necessary tools and equipment, and using the previously installed three-way switch system, add a four-way switch to control the light from three locations according to NEC specifications.

(1) Purpose of four-way switches

(2) Operation of four-way switches

(3) Circuitry

4h. Given a length of 3/4" EMT, a fused disconnect, tools and the necessary equipment, install conduit and feeder conductors between main panel and disconnect to meet NEC specifications.

(1) Purpose

(2) Circuitry

4i. Provided a work area, necessary tools and equipment, install a 220 volt receptacle in 3/4" EMT according to NEC specifications.

(1) Purpose

(2) Circuitry

APPLICATION:

WB 3ABR54230-1-III-4, Conduit Wiring, Projects 7,8, and 9

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-5, Circuit Extensions
SG 3ABR542 30-1-III-6, Low Voltage Circuits

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/29May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Circuit Extensions (Day 28)

LESSON DURATION

CLASSROOM/LABORATORY 3 Hrs	COMPLEMENTARY 1 Hr	TOTAL 4 Hrs

POI REFERENCE

PAGE NUMBER 25	PAGE DATE 1 May 75	PARAGRAPH 5

STS/CTS REFERENCE

NUMBER 542X0, Changes 1, 2, 3, 4, and 5	DATE 2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hand Tool Set Projector, Overhead	Multimeter, Clamp-on Type AN/USM-33	None	SG III-5, WB III-5 NATIONAL ELECTRICAL CODE NATIONAL ELECTRICAL CODE AND BLUEPRINT READING TRANSPARENCIES, CIRCUIT EXTENSION

CRITERION OBJECTIVES AND TEACHING STEPS

5a. Given circuit extension information and a list of problems, find the answer to each problem.

(1) Types of circuit extensions
(2) Purpose of circuit extensions

5b. Provided a work area, necessary tools and equipment, install a circuit in surface metal raceway from an existing outlet according to NEC specifications.

(1) Purpose
(2) Selection
(3) Fittings
(4) Installation
(5) Circuitry

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

5c. Using previously installed circuits and meter, balance circuits according to NEC specifications

(1) Purpose
(2) Proper procedures
(3) NEC requirements

Course No: 3ABR54230-1
Day: 28

Branch Approval: Billy S Littlejohn
Date: 26 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (2 Hours 45 Minutes)

PRESENTATION:

5a. Given circuit extension information and a list of problems, find the answer for each problem.

(1) Types of circuit extensions

(2) Purpose of circuit extensions

5b. Provided a work area, necessary tools and equipment, install a circuit in surface metal raceway from an existing outlet according to NEC specifications.

(1) Purpose

(2) Selection

(3) Fittings

(4) Installation

(5) Circuitry

5c. Using previously installed circuits and meter, balance circuits according to NEC specifications.

(1) Purpose

(2) Proper procedures

(3) NEC requirements

APPLICATION:

WB 3ABR54230-1-III-5, Circuit Extensions Projects 1, 2 and 3

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

None

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/29May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Low Voltage Circuits (Day 28)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
2 Hrs	1 Hr	3 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
26	1 May 75	6

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hand Tool Set Projector, Overhead	None	None	SG III-6; WB III-6 NATIONAL ELECTRICAL CODE NATIONAL ELECTRICAL CODE AND BLUEPRINT READING TRANSPARENCIES, INSTALLATION OF LOW VOLTAGE CIRCUITS

CRITERION OBJECTIVES AND TEACHING STEPS

6a. Provided a work area, tools and necessary equipment, install a low-voltage circuit according to NEC specifications.

(1) Purpose and use of low-voltage circuits
(2) Components used in low-voltage circuits
(3) NEC requirements

Course No: 3ABR54230-1
Day: 28

Branch Approval: Bobby G [illegible]
Date: 26 Aug 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (1 Hour 45 Minutes)

PRESENTATION:

6a. Provided a work area, tools and necessary equipment, install a low voltage circuit according to NEC specifications.

(1) Purpose and use of low voltage circuits

(2) Components used in low voltage circuits

(3) NEC requirements

APPLICATION:

WB 3ABR54230-1-III-6, Low Voltage Circuits

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: None

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/29May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Troubleshooting Conduit Circuits (Days 28 thru 30)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
8 Hrs	2 Hrs	10 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
28	1 May 75	7

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Conduit Troubleshooting Test Board Hand Tool Set Projector, Over head	Multimeter	None	SG III-7; WB III-7 NATIONAL ELECTRICAL CODE NATIONAL ELECTRICAL CODE AND BLUEPRINT READING TRANSPARENCIES, TROUBLESHOOTING

CRITERION OBJECTIVES AND TEACHING STEPS

7a. Provided a multimeter and instructions, troubleshoot an energized (120/240 volt) circuit to locate troubles inserted in the circuit by the instructor.

(1) Types of circuit troubles
(2) Test equipment
(3) Methods and procedures for troubleshooting

7b. Provided a multimeter and instructions, troubleshoot a de-energized electrical circuit to locate troubles inserted by the instructor.

(1) Types of circuit troubles
(2) Test equipment
(3) Methods and procedures for troubleshooting

ATC FORM AUG 73 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

7c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.

Course No: 3ABR54230-1 Branch Approval: Betty G Littlejohn
Days: 28, 29 and 30 Date; 26 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (7 Hours 45 Minutes)

PRESENTATION:

7a. Provided a multimeter and instructions, troubleshoot an energized (120/240 volt) circuit to locate troubles inserted in the circuit by the instructor.

(1) Types of circuit troubles

CONCLUSION (Day 28)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-7, Troubleshooting Conduit Circuits

INTRODUCTION (Day 29)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

7a. (Continued)

(2) Test equipment

(3) Methods and procedures for troubleshooting

7b. Provided a multimeter and instructions, troubleshoot a deenergized electrical circuit to locate troubles inserted by the instructor.

(1) Types of circuit troubles

(2) Test equipment

(3) Methods and procedures for troubleshooting

7c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.

APPLICATION:

WB 3ABR54230-1-III-7, Troubleshooting Conduit Circuits, Projects 1 and 2 (and part of 3)

CONCLUSION (Day 29)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-III-8, Appliance Maintenance

INTRODUCTION (Day 30)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

PRESENTATION:

7c. (Continued from Day 29)

APPLICATION:

Complete WB 3ABR54230-1-III-7, Troubleshooting Conduit Circuits, Project 3

CONCLUSION (Unit 7)

SUMMARY:

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/29May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER III	BLOCK TITLE Conduit Wiring

LESSON TITLE
Appliance Maintenance (Day 30)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
3 Hrs	2 Hrs	5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
29	1 May 75	8

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Electrical Components Projector, Overhead	None	None	SG III-8; WB III-8 NATIONAL ELECTRICAL CODE NATIONAL ELECTRICAL CODE AND BLUEPRINT READING TRANSPARENCIES, APPLIANCES

CRITERION OBJECTIVES AND TEACHING STEPS

8a. Given information pertaining to appliance maintenance, list the correct solution to each problem.

(1) Types of appliances
(2) Appliance components
(3) Installation requirements
(4) Troubleshooting appliances

ATC FORM AUG 72 770

Course No: 3ABR54230-1
Day 30

Branch Approval: Bobby G. Littlejohn
Date: 26 May 75

PART II

INTRODUCTION (5 Minutes)

REVIEW PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (2 Hours 45 Minutes)

PRESENTATION:

8a. Given information pertaining to appliance maintenance, list the correct solution to each problem.

(1) Types of appliances

(2) Appliance components

(3) Installation requirements

(4) Troubleshooting appliances

APPLICATION:

WB 3ABR54230-1-III-8, Appliance Maintenance

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: None

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER IV	BLOCK TITLE Motors and Controls

LESSON TITLE
Three-Phase Motor Systems (Days 31, 32, 33, and 34)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
24 Hrs	8 Hrs	32 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
31	1 May 75	1

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
TRAINER, ROTATING MAGNETIC FIELD; TRAINER, MOTOR AND MOTOR CONTROL; TRAINER, AC MOTOR INSTALLATION DEMONSTRATOR: TRAINER, OPERATION OF FLOAT SWITCH CONTROL; HAND TOOL SET	Projector, 16mm		SG IV-1; WB IV-1; NATIONAL ELECTRICAL CODE; NATIONAL ELECTRICAL CODE AND BLUEPRINT READING TF 1-566-A, MOTOR CONNECTIONS TF 6082, MOTOR CONTROLLERS

CRITERION OBJECTIVES AND TEACHING STEPS

1a. Given the required information, select the equipment necessary to install a three-phase motor to power so the installation will meet NEC and manufacturer's specifications.

- (1) Select a three-phase motor
    - (a) Types of motors
    - (b) Motor components
    - (c) Theory of operation
- (2) Wire size and type
- (3) Type and size of conduit
- (4) Mechanical connection to load

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1b. Using a three-phase motor trainer and previously selected equipment, install and operate a three-phase motor on high voltage. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Identify motor leads

(a) WYE
(b) DELTA

(3) Installation of leads
(4) NEC specifications
(5) Manufacturer's specifications

1c. Using a three-phase motor trainer and previously selected equipment, connect and operate a three-phase motor on low voltage. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Identify motor leads
(3) NEC specifications
(4) Manufacturer's specifications

1d. Using a three-phase motor trainer with previously installed three-phase motor, change power leads to reverse the direction of rotation to meet NEC and manufacturer's specifications.

(1) Interpret wiring diagram
(2) Identify motor leads
(3) Select leads for reversing
(4) NEC specifications
(5) Manufacturer's specifications

1e. Using a three-phase motor trainer, select an adequate motor overload protective device in accordance with the NEC, motor data plate and manufacturer's specifications.

(1) Types of controllers
(2) Types of overload devices
(3) Overload selection
(4) Overload adjustments
(5) Interpret wiring diagrams

1f. Using a three-phase motor trainer, install a start/stop station to a three-phase magnetic controller to control a three-phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagram
(2) Across the line magnetic controllers
(3) Switch design
(4) Switch installation
(5) NEC specifications
(6) Manufacturer's specifications

1g. Using a three-phase motor trainer, install two start/stop stations to a three-phase magnetic controller to control a three-phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagram
(2) Multi-switch installation
(3) NEC specifications
(4) Manufacturer's specifications

1h. Using a three-phase motor trainer, install a thermostatic control to a three-phase magnetic controller to control the operation of a three-phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagram
(2) Thermostat control design
(3) Other related controls
(4) Thermostat installation
(5) NEC specifications
(6) Manufacturer's specifications

1i. Using a three-phase motor trainer, install a reversing start/stop station and a magnetic controller to control the direction of rotation of a three-phase motor in accordance with NEC and manufacturer's specifications.

(1) Interpret wiring diagram
(2) Reversing magnetic controllers
(3) Reversing start/stop station
(4) System installation
(5) NEC specifications
(6) Manufacturer's specifications

Course: 3ABR54230-1
Days: 31, 32, 33, 34

Branch Approval: Bobby S Littlejohn
Date: 27 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (23 Hours 45 Minutes)

PRESENTATION:

1a. Given the required information, select the equipment necessary to install a three phase motor to power to meet NEC and manufacturer's specifications.

(1) Select a three phase motor

(a) Types of motors

1 AC

2 DC

3 Universal

4 Types AC

a 1Ø

b 3Ø

5 Type 3 Ø

  a Sychronous

  b Induction

6 Motor data plates

(b) Motor components

1 Stator

2 Rotor

3 End bells

(c) Theory of operation

1 Define a motor

2 Types of induction

3 Rotating magnetic field

4 Squirrel cage rotor

5 Reversing motor

(2) Wire size and types

(3) Type and size conduit

(4) Mechanical connection to load

APPLICATION:

WB 3ABR54230-1-IV-1, Three Phase
Motor System, Project 1, 2, and 3

CONCLUSION (Day 31)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-1, Three Phase
Motor Systems

INTRODUCTION (Day 32)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

1b. Using a three phase motor trainer and previously selected equipment, install and operate a three phase motor on high voltage. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Identify motor leads

   (a) Wye

   (b) Delta

(3) Installation of leads

(4) NEC specifications

(5) Manufacturer's specifications

1c. Using a three phase motor trainer and previously selected equipment, connect and operate a three phase motor on low voltage. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Identify motor leads

(3) NEC specifications

(4) Manufacturer's specifications

1d. Using a three phase motor trainer with previously installed three phase motor, change power leads to reverse the direction of rotation to meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Identify motor leads

(3) Select leads for reversing

(4) NEC specifications

(5) Manufacturer's specifications

1e. Using a three phase motor trainer, select an adequate motor overload protective device IAW the NEC, motor data plate and manufacturer's specifications.

(1) Types of controllers

(a) Across-the-line

(b) Reduced voltage

(2) Types of overload devices

(a) Thermal

1 Melting alloy

2 Bi-metal

(b) Magnetic

APPLICATION:

WB 3ABR54230-1-IV-1, Three Phase
Motor Systems, Project 4, 5 and 6

CONCLUSION (Day 32)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-1, Three Phase
Motor System

INTRODUCTION (Day 33)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

1e. Continued from Day 32

(3) Overload selection

(4) Overload adjustments

(5) Interpret wiring diagrams

1f. Using a three phase motor trainer install a start/stop station to a three phase magnetic controller to control a three phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagram

(2) Across-the-line magnetic controllers

(3) Switch design

(4) Switch installation

(5) NEC specifications

(6) Manufacturer's specifications

APPLICATION:

WB 3ABR54230-1-IV-1, Three Phase
Motor Systems, Projects 7, 8, 9
and 10

CONCLUSION (Day 33)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-1, Three Phase
Motor Systems

INTRODUCTION (Day 34)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

(4) System installation

(5) NEC specifications

(6) Manufacturer's specifications

APPLICATION:

WB 3ABR54230-1-IV-1, Three Phase Motor Systems, Projects 11, 12 and 13

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION

SUMMARY:

Cover main points of lesson.

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-2, Troubleshooting Three Phase Motor Systems

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER IV	BLOCK TITLE Motors and Controls

LESSON TITLE

Troubleshooting Three-Phase Motor Systems (Day 35)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	2 Hrs	8 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
33	1 May 75	2

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Motor and Motor Control Hand Tool Set	Multimeter Megohmmeter	None	SG IV-2 WB IV-2 National Electrical Code

CRITERION OBJECTIVES AND TEACHING STEPS

2a. Using a three-phase motor and trainer, inspect the motor installation in accordance with manufacturer's specifications.

(1) Visual inspection
(2) Operational inspection

2b. Given a three-phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.

(1) Motor data plates
(2) Three-phase motor and controller schematics
(3) Electrical test
(4) Repair procedures
(5) Test equipment

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

2c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.

(1) Good housekeeping
(2) Safety practices

Course No: 3ABR54230-1
Day: 35

Branch Approval: Bobby G Littlejohn
Date: 27 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hours 45 Minutes)

PRESENTATION:

2a. Using a three phase motor and trainer, inspect the motor installation in accordance with manufacturer's specifications.

(1) Visual inspection

(2) Operational inspection

2b. Given a three phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.

(1) Motor data plates

(2) Three phase motor and controller schematics

(3) Electrical test

(4) Repair procedures

(5) Test equipment

2c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.

(1) Good housekeeping

(2) Safety practices

APPLICATION:

WB 3ABR54230-1-IV-2, Troubleshooting Three Phase Motor Systems, Projects 1 and 2

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (Day 35)

SUMMARY:

Cover main points of lesson.

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-3, Single Phase Motor Systems

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER IV	BLOCK TITLE Motors and Controls

LESSON TITLE
Single-Phase Motor Systems (Days 36, 37, and 38)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
18 Hrs	6 Hrs	24 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
34	1 May 75	3

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70, (14 Jan 72, 6 Mar 73, 18 Apr 73, 24 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Motor and Motor Control Trainer, Electric Motor Exploded Hand Tool Set	Projector, 16mm	None	SG IV-3; WB IV-3 TF 56606 SINGLE-PHASE MOTOR CONNECTIONS: TF [illegible]06, MOTOR CONTROL SYSTEM; NATIONAL ELECTRICAL CODE AND BLUEPRINT READING; NATIONAL ELECTRICAL CODE

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Given the required information, select the equipment necessary to install a single-phase motor to a power source. Installation must meet NEC and manufacturer's specifications.

(1) Select a single-phase motor

  (a) Types of motors
  (b) Motor components
  (c) Theory of operation

(2) Wire size and type
(3) Type and size of conduit

ATC FORM AUG 73 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

3b. Using a single-phase motor trainer and previously selected equipment, install and operate a single-phase motor for low voltage operation. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Identify motor leads
(3) Installation of leads
(4) NEC specifications
(5) Manufacturer's specifications

3c. Using a single-phase motor trainer and previously installed equipment, connect and operate a single-phase motor for high voltage operation. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Identify motor leads
(3) NEC specifications
(4) Manufacturer's specifications

3d. Using a single phase motor trainer with previously installed single-phase motor, change motor leads to reverse the direction of rotation in accordance with NEC manufacturer's specification.

(1) Interpret wiring diagrams
(2) Identify motor leads
(3) NEC specifications
(4) Manufacturer's specifications

3e. Using a single-phase motor trainer, install a drum switch to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Switch design
(2) Switch installation
(3) NEC specification
(4) Manufacturer's specification

3f. Using a single-phase motor trainer, install one start/stop station to a single-phase magnetic controller to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Across the line magnetic controller
(3) Switch design
(4) Switch installation
(5) NEC specifications
(6) Manufacturer's specifications

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

3g. Using a single-phase motor trainer, install two start/stop stations to a single-phase magnetic controller to control the operation of a single-phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Switch installation
(3) NEC specifications
(4) Manufacturer's specifications

3h. Using a single-phase motor trainer, install a thermostatic control to previously installed magnetic controller to operate a single-phase motor system. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Thermostat control design
(3) Thermostat control installation
(4) NEC specifications
(5) Manufacturer's specifications

3i. Using a single-phase motor trainer, install a hand-off-automatic switch and thermostat to previously installed single-phase magnetic controller to operate a single-phase motor system. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams
(2) Switch design
(3) Switch installation
(4) NEC specifications
(5) Manufacturer's specifications

Course: 3ABR54230-1
Days: 36, 37, 38

Branch Approval: Bobby S Littlejohn
Date: 27 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (23 Hours 45 Minutes)

PRESENTATION:

3a. Given the required information, select the equipment necessary to install a single phase motor to a power source, installation must meet NEC and manufacturer's specifications.

(1) Select a single phase motor

(a) Types of motors

1 Induction

2 Repulsion

3 Universal

(b) Motor components

1 Rotor

2 Stator

3 End bells

4 Centrifugal switch

(c) Theory of operation

1 Induction motors

2 Repulsion motors

3 Universal

(2) Wire size and type

(3) Type and size of conduit

APPLICATION:

WB 3ABR54230-1-IV-3, Single Phase Motor System, Projects 1 and 2

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CONCLUSION (Day 36)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-3, Single Phase
Motor Systems

INTRODUCTION (Day 37)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

3b. Using a single phase motor trainer and previously selected equipment, install and operate a single phase motor for low voltage operation. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Identify motor leads

(3) Installation of leads

(4) NEC specifications

(5) Manufacturer's specifications

3c. Using a single phase motor trainer and previously installed equipment, connect and operate a single phase motor for high voltage operation. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Identify motor leads

(3) NEC specifications

(4) Manufacturer's specifications

3d. Using a single phase motor trainer with previously installed single phase motor, change motor leads to reverse the direction of rotation in accordance with NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Identify motor leads

(3) NEC specifications

(4) Manufacturer's specifications

3e. Using a single phase motor trainer, install a drum switch to control the operation of a single phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Switch design

(2) Switch installation

(3) NEC specification

(4) Manufacturer's specification

APPLICATION:

WB 3ABR54230-1-IV-3, Single Phase Motor Systems, Projects 3, 4, and 5

105

CONCLUSION (Day 37)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-3, Single Phase
Motor Systems

INTRODUCTION (Day 38)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

3f. Using a single phase motor trainer, install one start/stop station to a single phase magnetic controller, to control the operation of a single phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Across-the-line magnetic controller

  (a) Load circuit

  (b) Control circuit

  (c) Start circuit

  (d) Holding circuit

(3) Switch design

(4) Switch installation

(5) NEC specifications

(6) Manufacturer's specifications

3g. Using a single phase motor trainer, install two start/stop stations to a single phase magnetic controller to control the operation of a single phase motor. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Switch installation

(3) NEC specifications

(4) Manufacturer's specifications

3h. Using a single phase motor trainer, install a thermostatic control to previously installed magnetic controller to operate a single phase motor system. Installation must meet NEC and manufacturer's specifications.

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(1) Interpret wiring diagrams

(2) Thermostat control design

(3) Thermostat control installation

(4) NEC specifications

(5) Manufacturer's specifications

3i. Using a single phase motor trainer, install a hand-off-automatic switch and thermostat to previously installed magnetic controller to operate a single phase motor system. Installation must meet NEC and manufacturer's specifications.

(1) Interpret wiring diagrams

(2) Switch design

(3) Switch installation

133

(4) NEC specifications

(5) Manufacturer's specifications

APPLICATION:

WB 3ABR54230-1-IV-3, Single Phase Motor Systems, Projects 6, 7, 8 and 9

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-4, Troubleshooting Single Phase Motor Systems

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER IV	BLOCK TITLE Motors and Controls

LESSON TITLE
Troubleshooting Single-Phase Motor Systems (Day 39)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	2 Hrs	8 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
36	1 May 75	4

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Motor and Motor Control Hand Tool Set	Multimeter Megohmmeter	None	SG IV-4 WB IV-4 National Electrical Code

CRITERION OBJECTIVES AND TEACHING STEPS

4a. Using a single-phase motor and trainer, inspect the motor installation in accordance with manufacturer's and NEC specifications.

(1) Visual inspection
(2) Operational inspection

4b. Given a single-phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.

(1) Motor data plates
(2) Single-phase motor and controller schematics
(3) Electrical test
(4) Mechanical test

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(5) Repair procedures
(6) Test equipment

4c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.

(1) Good housekeeping
(2) Safety practices

Course No: 3ABR54230-1
Day 39

Course Approval: Bobby G Littlejohn
Date: 27 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hours 55 Minutes)

PRESENTATION:

4a. Using a single phase motor and trainer, inspect the motor installation in accordance with manufacturer's and NEC specifications.

- (1) Visual inspection
  - (a) Lubrication
  - (b) Bearings
  - (c) Cleanliness
  - (d) Motor wiring
- (2) Operational inspection

(a) Sound

(b) Temperature

(c) Current draw (FLC)

4b. Given a single-phase motor and control system with electrical faults and test equipment, repair faults to meet manufacturer's and NEC specifications.

(1) Motor data plates

(2) Single-phase motor and controller schematics

(3) Electrical test

(a) Voltage

    (b) Full load current

    (c) Winding resistance

    (d) Insulation breakdown

(4) Mechanical test

(5) Repair procedures

(6) Test equipment

    (a) Voltmeter

    (b) Ammeter

    (c) Ohmmeter

    (d) Megohmmeter

4c. Using tools and instructions provided, disconnect electrical circuits, sort materials and store in designated storage facilities.

(1) Good housekeeping

(2) Safety practices

APPLICATION:

WB 3ABR54230-1-IV-4, Troubleshooting Single Phase Motor Systems, Projects 1 and 2

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY: Cover main points of lesson.

STUDY ASSIGNMENT:

SG 3ABR54230-1-IV-5, Motor Generator,
Control Panels and Circuit Breakers

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER IV	BLOCK TITLE Motors and Controls

LESSON TITLE
Motor Generators, Control Panels and Circuit Breakers (Day 40)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
4 Hrs	2 Hrs	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
37	1 May 75	5

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 24 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Motor Control Center and Motor Generator Set Trainer, Line Alternator Motor Control	None	None	SG IV-5 WB IV-5 National Electrical Code and Blueprin Reading

CRITERION OBJECTIVES AND TEACHING STEPS

5a. Using information provided, write the purpose of a motor control center and list its major components.

(1) Purpose of a motor control center
(2) Parts of a motor control center

5b. Using information provided, write the purpose of a motor generator set and list its major components.

(1) Purpose of a motor generator set
(2) Parts of a motor generator set
(3) Operation of a motor generator set

ATC FORM AUG 72 770

Course No: 3ABR54230-1 Branch Approval: Bobby G Littlejohn
Day 40 Date: 27 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (3 Hours 55 Minutes)

PRESENTATION:

5a. Using information provided, write the purpose of a motor control center and list its major components.

(1) Purpose of a motor control center

(2) Part of a motor control center

5b. Using information provided, write the purpose of a motor generator set and list its major components.

(1) Purpose of a motor generator set

(2) Parts of a motor generator set

(3) Operation of a motor generator set

APPLICATION:

WB 3ABR54230-1-IV-5, Motor Generator, Control Panels and Circuit Breakers, Projects 1, 2, and 3

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

Cover main points of lesson.

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-V-1, Intrusion Alarm System

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25June75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER V	BLOCK TITLE Controls and Alarm Systems

LESSON TITLE
Intrusion Alarm Systems (Days 41, 42, and 43)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
18 Hrs	0	18 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
38	1 May 1975	1

STS/CTS REFERENCE

NUMBER	DATE
542X0, Chgs 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Intrusion Alarm Multimeter Projector, Overhead	None	None	SG V-1 WB V-1 Transparencies, Intrusion Alarm Systems

CRITERION OBJECTIVES AND TEACHING STEPS

1a. Given information pertaining to intrusion alarm systems, inspect and service electrical systems and components.

(1) Purpose and types of intrusion alarm systems
(2) Operating principles
(3) Components and usage
(4) Wiring diagrams
(5) Inspection requirements
(6) Purpose and types of service
(7) Servicing instructions

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

1b. Using meter, trainer, and wiring diagram, troubleshoot and repair electrical systems and components of intrusion alarm systems.

(1) Purpose of troubleshooting
(2) Types of troubles
(3) Wiring diagrams
(4) Troubleshooting procedures
(5) Repair procedures

☆ GPO: 1972 779-386/24

Course No: 3ABR54230-1
Days: 41, 42, 43

Branch Approval: Bobby G. Littlejohn
Date: 20 Jun 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (17 Hours 45 Minutes)

PRESENTATION:

1a. Given information pertaining to intrusion alarm systems, inspect and service electrical systems and components.

(1) Purpose and types of intrusion alarm systems

(2) Operating principles

(3) Components and usage

(4) Wiring diagrams

APPLICATION:
WB 3ABR54230-1, Intrusion alarm system project 1 and 2

CONCLUSION (Day 41)

SUMMARY:

STUDY ASSIGNMENT:
SG 3ABR54230-1, Intrusion
alarm systems

INTRODUCTION (Day 42)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

(5) Inspection requirements

(6) Purpose and types of Service

(7) Servicing Instructions

CONCLUSION (Day 42)

SUMMARY:

STUDY ASSIGNMENT:
SG3ABR54230-1-V-1, Intrusion alarm systems

INTRODUCTION (Day 43)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

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OVERVIEW:

MOTIVATION:

PRESENTATION:

1b. Using meter, trainer and wiring diagram, troubleshoot and repair electrical systems and components of intrusion alarm systems.

(1) Purpose of troubleshooting

(2) Types of troubles

(3) Wiring diagram

(4) Troubleshooting

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(5) REPAIR PROCEDURES

APPLICATION:
WB 3ABR54230-1-V-1, Intrusion alarm systems project 3 and 4

EVALUATION:
Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: SG 3ABR54230-1-V-2, Fire Alarm systems

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25June75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER V	BLOCK TITLE Controls and Alarm Systems

LESSON TITLE
Fire Alarm Systems (Days 44 and 45)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
8 Hrs	0	8 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
39	1 May 1975	2

STS/CTS REFERENCE

NUMBER	DATE
542X0, Chgs 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Fire Alarm Systems Multimeter Hand Tool Set Projector, Overhead	None	None	SG V-2 WB V-2 Transparencies, Fire Alarm Systems

CRITERION OBJECTIVES AND TEACHING STEPS

2a. Given information pertaining to a fire alarm system, trainer and wiring diagram, identify components and trace electrical circuits.

(1) Purpose and types of fire alarm systems
(2) Operating principles
(3) Components and usage
(4) Wiring diagram
(5) Inspection requirements

2b. Given fire alarm trainer, inspect and service electrical systems and components.

(1) Purpose of service
(2) Components
(3) Service instructions

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

2c. Given a fire alarm trainer and meter, troubleshoot and repair electrical systems and components.

(1) Types of troubles
(2) Troubleshooting procedure
(3) Wiring diagrams
(4) Repair procedures

Course No: 3ABR54230-1 Branch Approval: Bobby G Littlejohn
Day: 44, 45 Date: 20 Jun 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

133

BODY (7 Hours 45 Minutes)

PRESENTATION:

2a. Biven information pertaining to a fire alarm system, trainer and wiring diagram, identify components and trace electrical circuits.

(1) Purpose and types of fire alarm systems

(2) Operating principles

(3) Components and usage

(4) Wiring diagram

(5) Inspection requirements

2b. Given fire alarm trainer, inspect and service electrical systems and components

(1) Purpose of Service

(2) Components

(3) Service Instructions

2c. Given a fire alarm trainer and meter, troubleshoot and repair electrical systems and components.

(1) Types of troubles

(2) Troubleshooting procedure

(3) Wiring diagrams

APPLICATION:
WB 3ABR54230-1-V-2, Fire alarm system
Project 1 and 2.

CONCLUSION (Day 44)

SUMMARY:

STUDY ASSIGNMENT:

INTRODUCTION (Day 45)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

(4) Repair procedures

APPLICATION:
WB 3ABR54230-1-V-2, Fire Alarm
Systems, cont Project 2

EVALUATION:

CONCLUSION (Day 45)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: SG 3ABR54230-1-V-3,
Cathodic Protection and corrosion
control

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/25June75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER V	BLOCK TITLE Controls and Alarms

LESSON TITLE
Cathodic Protection and Corrosion Control (Day 45)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
2 Hrs	0	2 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
40	1 May 1975	3

STS/CTS REFERENCE

NUMBER	DATE
542X0, Chgs 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Impressed Current Cathodic Protection System	None	None	SG V-3 WB V-3

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Given information pertaining to corrosion, match correct terms with definitions.

(1) Define corrosion
(2) Identify parts of a corrosion cell
(3) Trace current flow in a corrosion cell

3b. Given information pertaining to cathodic protection, complete statements to identify methods of cathodic protection.

(1) Galvanic anode method
(2) Impressed current method

ATC FORM AUG 72 770

Course No: 3ABR54230-1
Day: 45

Branch Approval: Bobby R Littlejohn
Date: 20 Jun 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (1Hr 45 Min)

PRESENTATION:

3a. Given information pertaining to corrosion, match correct terms with definitions.

(1) Define corrosion

(2) Identify parts of a corrosion cell

(3) Trace current flow in a corrosion cell

3b. Given information pertaining to cathodic protection, complete statements to identify methods of cathodic protection.

(1) Galvanic anode method

(2) Impressed current method

APPLICATION:

WB 3ABR54230-1-V-3, Cathodic Protection and corrosion control

EVALUATION:

Evaluate by oral, written questions, and/or observation of students' performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: NONE

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STUDY GUIDES 3ABR54230-1-III-1 thru 8

Department of Civil Engineering Training

Electrician

Block III

CONDUIT WIRING

JULY 1975

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

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ELECTRICIAN

(Days 21 - 30)

PROJECT TITLE PAGE

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This supersedes 3ABR54230-1-III-1 thru 8, July 1973
Previous editions may be used.

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-III-1
July 1975

PUBLICATIONS

OBJECTIVE

This unit of instruction is to provide guidance in the use of technical orders, and standard and commercial publications.

INTRODUCTION

It is no longer necessary to memorize technical data and other information required to perform all duties of a trade. Written material has been published making this information available. Becoming proficient in the use of Air Force publications will allow you to perform specific tasks without memorizing procedures.

INFORMATION

PUBLICATIONS

You will use a study guide that has been prepared for several career fields. This is the study guide titled "Publications" for AFS 53, 54, 55, 56.

REFERENCES

1. AFR 0-2

2. TO 00-5-1

3. National Electrical Code

POWER TOOLS

OBJECTIVE

To familiarize you with the proper use and care of the drill press, electric drill, and bench grinder.

INTRODUCTION

When installing circuits, regardless if it be in conduit or nonmetallic sheathed cable, there are certain situations when power tools should be used. By using power tools you will be able to do the job faster, easier and, in many cases, neater.

INFORMATION

IDENTIFICATION AND USE OF ELECTRIC DRILLS

Electric drills are powered with a universal motor for ac and dc operation. Bearings are factory lubricated for lifetime service. The electric cord is a three-conductor cable with a ground wire and plug. The ground wire should always be connected to a suitable ground before using the drill. The metal case of the drill is thus grounded to protect the user. Hardly a year goes by without someone being killed by using an electric drill which was not properly grounded.

The process of drilling holes in metal with an electric drill is similar to drilling by hand except the power for turning the drill is furnished by an electric motor instead of the operator. Electric drills commonly used have capacities for drilling holes from 1/16 inch up to 3/4 inch in diameter. Figure 1 shows a popular type of an electric drill. Drills of this type are equipped either with a pistol grip or spade (closed)handle. Ordinarily, straight shank twist drills are used in electric drills. They are secured in a key-type gear chuck which automatically centers the drill shank. Many electric drills can be fitted with attachments for driving screws, rotation of small wheels, drilling at right angles, and other special work.

When drilling metal with the electric drill, the user must first be sure that the diameter of the hole to be drilled is within the capacity of the tool. The size of an electric drill is usually determined by the size of its chuck. For instance, a 1/2-inch drill is equipped with a chuck that will take a twist drill 1/2 inch in diameter, and no larger. Using a larger twist drill than is recommended should be practiced only during an emergency. Overloading an electric drill in this manner may either stall or overheat the drill motor. Continued stalling and overheating will damage the drill motor to a point where it will become useless.

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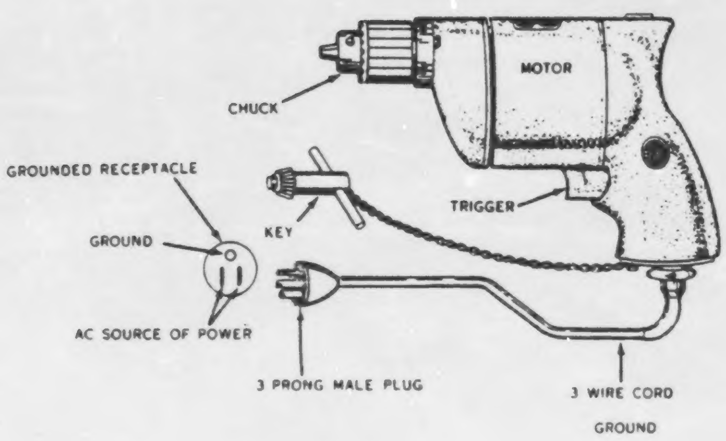

Figure 1. Electric Drill

When drilling holes, care must be used to hold the electric drill at a right angle to the surface that is being drilled. With the tool held in that manner, exert a light pressure on the drill for continued drilling. If the hole is to be drilled through the work, relieve the pressure on the drill when the point of the twist drill begins to break through the metal. Exert only light pressure to complete drilling the hole. Finally, pull the drill straight back until the twist drill is withdrawn from the hole, then shut off the drill motor. You should remember that twist drills do not pull themselves into the work; they must be fed by pressure exerted by the operator.

Maintenance of Power Drills

The drill should be oiled in accordance with manufacturer specifications. The ventilation holes on the drills should be kept free of dust or lint to prevent overheating of the motor. The chuck should be kept clean and oiled to prevent rust or corrosion.

IDENTIFICATION AND USE OF A BENCH GRINDER

The bench grinder, shown in figure 2, is a tool used for hand grinding operations, such as sharpening chisels, screwdrivers, drills, and punches; removing excess metal from work; and smoothing metal surfaces. It is usually fitted with both medium and fine grain abrasive wheels. These abrasive wheels may be removed and other wheels substituted for them. Such wheels may include wire brushing wheels, buffing wheels, or polishing wheels. The work rest should be kept about 1/8 inch from the wheel. The rest serves to steady the work held against it.

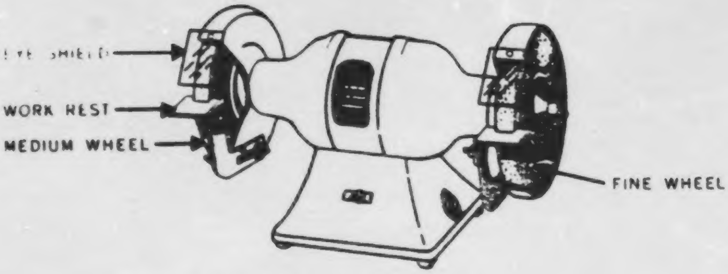

Figure 2. Bench Grinder

Remember, the abrasive wheel which grinds metal can also grind human fingers easily. The work should be held firmly and at the correct angle on the work rest provided on the grinder. It should be fed into the wheel with enough pressure to remove the desired amount of metal without generating too much heat. As often as necessary, cool off the edges of tools being ground to prevent drawing of temper.

Operation of the Bench Grinder

Several precautions should be observed prior to using the bench grinder. Before applying power to the grinder, a visual inspection should be made to assure that the grinding wheels are securely mounted to the shaft, that they are centered and free of cracks or breaks. Because the grinder turns at a high rate of speed and torque, a cracked or broken wheel may disintegrate and injure the operator. Check to see that the grinder is securely mounted. Loose or missing bolts can allow the grinder to shift or turn causing damage to the equipment or the operator. Check the area and floor to make sure sufficient room is available to move the material being ground, and that the floor is free of oil, grease or other loose material that could cause poor footing. Adjust the work rest to the proper angle for the work being done, making sure that the work cannot be caught between the work rest and the grinding wheel. Select the proper grinding wheel for the work being done. This normally means that the coarse wheel will be used to grind the work roughly to size while the fine wheel will be used to finish the work.

Keep the eye shield in place and also wear goggles. The eye shield is not total protection from tiny pieces of red-hot metal or stone. Protect your hands. Remember the metal can become very hot. Hold the work securely and do not force it against the wheel. Even though the grinder is turned off after it has been energized, it will take some time for it to wind down and stop due to the inertia stored in the grinding wheels and motor armature. Be sure the wheels are completely stopped before touching the grinder wheels.

Maintenance of Bench Grinders

The abrasive wheels should be replaced when they become worn or rounded. The electric motor which drives the abrasive wheels should be lubricated as the manufacturer specifications require. Periodically, the wheel guards should be removed and cleaned. Dust, dirt, abrasive compounds and work filings collect inside the wheel guards. Be certain the power source is disconnected before removing the wheel guards.

IDENTIFICATION AND USE OF DRILL PRESSES

The drill press was originally a metal working tool. The new type, however, may be used for drilling metal or wood. The main parts of the drill press are a polished steel post fastened to the cast-iron base, a table for holding the work, and a motor-driven head which is mounted at the top of the post. The head of the drill press has a boring spindle that turns inside a quill. The spindle has a cone-shaped pulley mounted on the top. The spindle is driven by a V-belt from a similar pulley mounted on the motor shaft. The cone pulleys mounted on the motor and the spindle make it possible to change the speed from 600 RPM to 5000 RPM. Different types of spindles can be used in the quill. The spindles may have chucks of different types. One has a chuck with a setscrew. The bit fits inside the chuck and is held in place by the setscrew. Another type has a keyless chuck in which the bit fits. The bit is clamped in place by hand. The most popular chuck, however, is the Jacobs chuck. This is a geared-type chuck and the bit is clamped in place with a gear-type key. Other chucks which require a special taper on the end of the bit are called Morse Taper Chucks.

Operation of the Drill Press

Prior to operation of the drill press you should perform the following checks. Check the area to assure that you have adequate room to work. Insure the floor is clean and free of grease and oil. Insure the drill speed will be correct for the material being drilled. Normally speaking, the harder the material the slower the drill speed. Set the drill table at the proper height for you. This height is normally even with the bottom of your breastbone. Select a sharp bit of the correct size and place in the drill chuck. Make sure the bit is centered in the chuck and all chuck jaws are contacting the bit shank. Operate the spindle with your hand to assure the spindle is free to turn. Move the operating lever to assure the drill bit can be raised and lowered. With your work in the drill vice lower the drill bit to where the point will just clear the bottom of the work and set the stop nuts at that position. Remove the work from the vise and locate the point to be drilled. Using a center punch, mark the pilot point for drilling by making a small indention in the stock, place the stock in the vise, and attach to the drill table with a "C" clamp after checking to see that the drill bit is lined over the index mark or indention. Connect the drill press to electrical power. Put on and adjust goggles. Check clothing and be sure all jewelry is removed. Turn on the drill press. Lower the drill to the work making sure that the drill tip contacts the point marked for drilling. Exert a light pressure on the operating lever. When the drill begins to cut the metal, raise the bit and check the location hole again. If the drill mark is centered on the pilot point, lower the drill bit and with a light, steady pressure bore the hole. Do not try to remove the shavings with your hands. They are extremely hot and sharp. Use a shop brush. When you feel the bit beginning to go through the bottom, relieve the pressure slightly on the operating handle. When the bit is completely through the metal, raise the bit, turn off the drill press and unclamp the vise from the table. Remove the work from the vise. Be careful as the work may be hot from drilling.

Maintenance of Drill Presses

The drill press should be cleaned after use. Metal shavings can lodge between the movable table and the polished steel post (column), which scratches the finish of the post. The finish protects the post from rust or corrosion. A light coat of vaseline on the post will inhibit rust, and also act as a lubricant. The drive motor should be lubricated as required by manufacturer's specification. The V-belts should be replaced if worn or frayed. Vaseline or a light grease should be applied to the spindle which will allow the spindle to pass smoothly through the quill.

SUMMARY

All electric powered equipment should be equipped with a suitable case ground. Electric drills are used for the purpose of drilling holes. Drills that use a self-centering chuck, are usually tightened with a key. One prime consideration for using a portable electric drill is to be sure that the work is within the capacity of the drill. Exert light pressure when using a portable drill. A bench grinder is used to dress or sharpen tools and metal stock. A visual inspection should be performed prior to use of the bench grinder for safety. Use all safety precautions when operating the grinder. The drill press is basically a fixed machine used for drilling. Use all safety precautions when operating the drill press.

QUESTIONS

1. What type of drill shank is normally used with a portable hand drill?
2. What problem may develop from continuous stalling of a hand drill?
3. How is the bit secured to the hand drill?
4. How are the bearings on a portable drill lubricated?
5. What will determine the adjustment of the work rest on the bench grinder?
6. What should the visual inspection of the grinding wheels include?
7. What precautions concerning clothing, and eye protection should be observed during the use of the bench grinder?
8. How should the work be secured when using a drill press?
9. What is used to control the depth of the twist bit in a drill press?
10. How should metal cutting be removed from the drill press?

REFERENCES

1. AFR 127-101, Ground Safety Accident Prevention Handbook.
2. TO 32-1-101, Maintenance and Care of Handtools.

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CONDUIT TOOLS, TERMS, AND MATERIAL

OBJECTIVE

This study guide is to provide a basic introduction of the tools, materials, terminology, and bends of conduit wiring.

INTRODUCTION

A conduit wiring system is an electrical system in which the circuit (wires, switches, outlets, etc) is enclosed within a rigid outer covering. This outer covering is used to protect and preserve the electrical circuit from mechanical injury. As you will see as you go through this block, this mechanical protection can be made of several materials and take many shapes or forms. In order to help you progress through this block, there are specialized tools, materials and terminology that belong specifically to conduit wiring. Being able to recognize and understand this information will greatly aid you in performing your job as an Air Force electrician.

INFORMATION

CONDUIT TOOLS

In addition to the tools you have used in the other blocks, you will be using tools that are special to conduit systems. These will be tools required to cut, ream, form, connect, and secure this external protection for the electrical circuit.

Cutting Tools

The two basic tools used for cutting conduit to length are the hacksaw or the pipe cutter.

The hacksaw is a tool made up of a frame and a replaceable, metal cutting blade. These blades differ in length, hardness and number of teeth per inch. Figure 3 shows a typical hacksaw and an assortment of hacksaw blades and their uses. Since these blades are hard and flexible, care must be exercised in their use to prevent the breaking of the blade. Some pointers to remember are: Keep the saw in line with the cut. Avoid excessive pressure. Assure that you have the proper blade for the material being cut.

While the hacksaw may be used to cut any type of conduit, the pipe cutter is restricted to rigid type conduit. Figure 4 shows a pipe cutter.

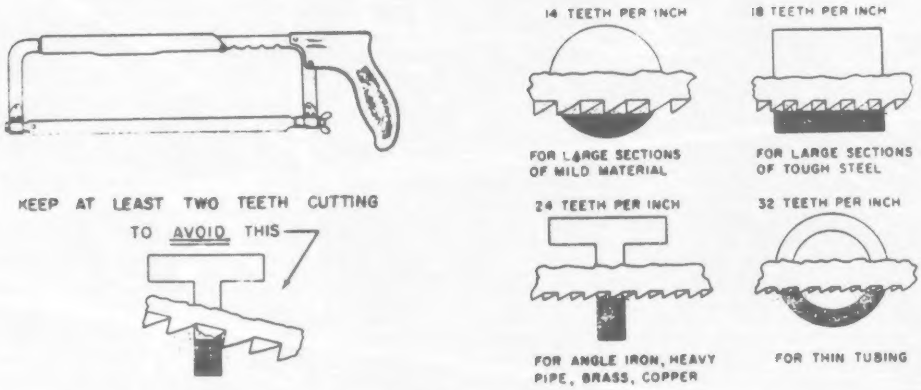

14 TEETH PER INCH
FOR LARGE SECTIONS OF MILD MATERIAL
18 TEETH PER INCH
FOR LARGE SECTIONS OF TOUGH STEEL
KEEP AT LEAST TWO TEETH CUTTING
TO AVOID THIS
24 TEETH PER INCH
FOR ANGLE IRON, HEAVY PIPE, BRASS, COPPER
32 TEETH PER INCH
FOR THIN TUBING

Figure 3. Hacksaw Blades and the Application

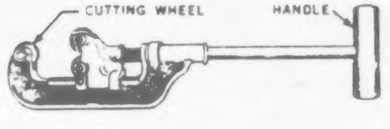

CUTTING WHEEL
HANDLE

Figure 4. Rigid Conduit Cutter

Pipe cutters come in several frame sizes to handle different diameters of rigid conduit. The cutter works by forcing a cutter wheel through the metal as the pipe cutter is rotated about the conduit. When using the pipe cutter remember: Keep the wheels and shaft threads oiled. Be sure that the cutter wheel is sharp. Avoid excessive tension on the cutter wheel when cutting.

Reaming Tools

After conduit is cut to length, the cut end must have the sharp edges removed to prevent damage to the wire insulation. This procedure is called "reaming." Rigid conduit is normally reamed with a tool similar to the drawing in figure 5.

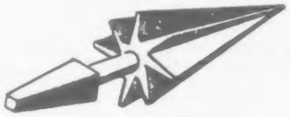


Figure 5. Pipe Reamer

Other tools used for reaming are rattail files, diagonal cutting pliers and lineman's pliers. The reaming is completed when the sharp edges and metal burrs have been removed.

Forming Tools

Conduit is purchased in straight pieces. Most generally it is necessary to form the pieces by bending to conform to the job requirements. This is done with special tools that will help bend the pipe without collapsing the walls of the pipe or reducing its inside diameter. The type tool used will depend on the type of conduit being formed. Figure 6 shows a conduit bender head that is used to form thinwall conduit (also called Electrical Metallic Tubing or EMT). A pipe handle about four-feet long screws into the shank of the head.

The tool used to manually bend rigid or thick-wall conduit is called a "Hickey." Only small diameter rigid conduit can be worked with this tool because of the force required to bend the thick-wall pipe. Figure 7 shows a Hickey head. A pipe handle is screwed to the shank.

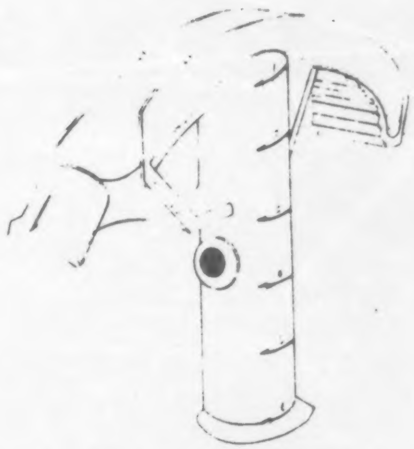


Figure 6. Conduit Bender

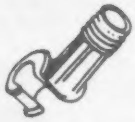


Figure 7. Hickey

If larger rigid conduit must be bent to conform to a job, a hydraulic bender as shown in figure 8 will be required.

The mechanical force required to bend the pipe is supplied by a hydraulic arm much the same as a car jack.

Connecting Tools

Thick-wall or rigid conduit will be joined together in the same way as gas or water pipe. That is, the ends will be threaded and the two pieces joined by a threaded coupling. To thread the ends of the pipe or conduit, a stock and threading die of the correct size is required. See figure 9.

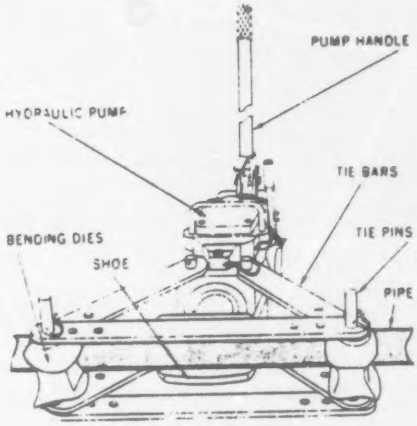


Figure 8. Hydraulic Bender

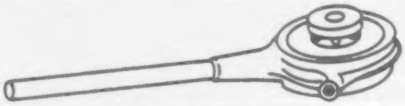
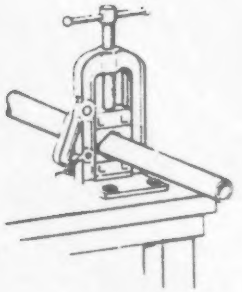
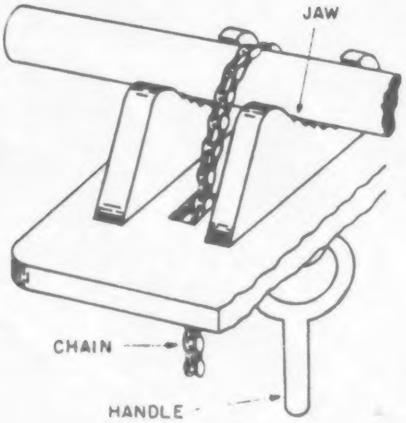


Figure 9. Nonadjustable Ratchet Stock and Dies

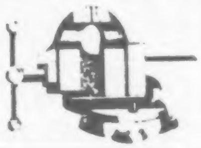
The stock is the part that holds the die and provides a handle for working leverage. The stock has a ratchet head. The dies are generally nonadjustable with replaceable cutting sections. To use the stock and die, assure that the conduit is held firmly in a vise. See figure 10.



Conventional Pipe Vise



A Chain Vise



Machinists Vises

Figure 10. Vises

Inspect the die to see that it is sharp and free of metal cuttings. Place the rough guide end of the die on the conduit and push the threading cutters against the pipe firmly with the heel of the hand. Take three or four short clockwise strokes to start the threads.

When the threads are started, cut the threads with a steady, even pressure on the stock handle until two threads show past the head of the die. The die should be oiled each two to three downward strokes. Use lard or sulphur pipe thread cutting oil to prevent overheating of the die. To remove the die from the threaded pipe, reverse the ratchet and turn the die stock counterclockwise.

For connecting thin-wall or EMT conduit, a dimpling tool is sometimes used. A connector of the proper size is inserted over the two ends of the conduit to be joined and the dimpling tool is used to make two small indentations or dimples on each end of the connector.

Another method of connecting EMT is with a split ring connector which we will cover later in the study guide.

The pipe wrench, shown in figure 11, is used by the electrician to fit rigid conduit together. The conduit should not be allowed to "bottom" in the jaw opening because the wrench will "kick off" and could cause injury to the user. Keep the wrench wiped clean and be sure the jaws are sharp and clean of dirt and grease so that they will not slip.

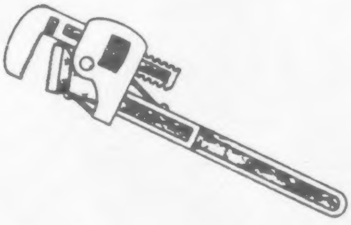
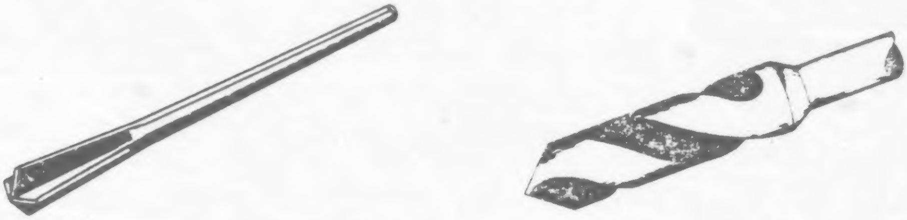


Figure 11. Pipe Wrench

Securing Tools

When conduit has been cut, formed, and coupled together, it must then be secured to the structure that it will supply. This is normally done with conduit straps of the correct size and type. The type of structure will determine what tools are required to secure the conduit to the structure by straps. If the structure is wood frame, probably nothing other than a claw hammer will be required. If the structure is under block or brick, you will probably need a star drill or a masonry bit such as those shown in figure 12.



Star Drill

Masonry Bit

Figure 12. Masonry Tools

These tools are used to punch or bore a hole to provide for the installation of toggle bolts or lead anchors. In some cases, a stud gun may be used. This tool drives stud bolts or nails by the use of gun powder as the propelling force. Only highly qualified personnel after extensive safety training should use a stud gun as it is extremely dangerous in unqualified hands.

Pulling Tools

After conduit wiring system is installed and supported, the Fish Tape is pushed through the conduit to allow the conductors to be pulled into the conduit from box to box. A Fish Tape is shown in figure 13.

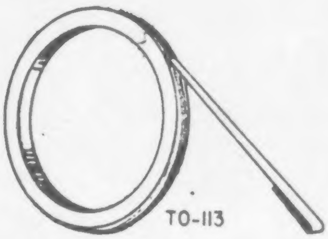


Figure 13. Fish Tape

MATERIALS

Rigid Conduit

Rigid metal conduit is constructed of thick wall pipe greatly resembling water or gas pipe. It differs mostly from standard plumbing by a smoother inside finish and being annealed to a softer metal. There are two types of rigid metal conduit: Galvanized and Black Enamel. For Air Force purposes, we will consider only the galvanized conduit due to the many restrictions and high cost of black enamel conduit. Galvanized rigid conduit can be used for all atmospheric conditions, exposed or concealed work. It requires fewer supports than other conduits. The size of the conduit is determined by its inside diameter and is supplied in 10-foot lengths.

Electrical Metallic Tubing

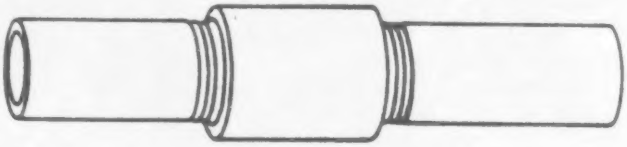
Electrical metallic tubing (EMT) is commonly called thinwall conduit. Due to its thin walls, EMT should NOT be threaded. The thinner walls of EMT offer less protection from physical damage and require more support than rigid. EMT should be cut with a hacksaw and fine tooth blade only. EMT conduit must be reamed after it is cut the same as rigid conduit.

Flexible Metal Conduit

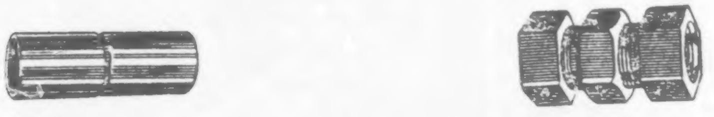
Flexible metal conduit is a specialized conduit that is used where minor adjustments of equipment are required or where vibration is present. It may be used in places where forming of bends in thinwall or rigid conduit would be too difficult. The bends in the flexible conduit should be secured to prevent the conduit from changing shape and bending the conductor.

Couplings

While we have discussed the use of couplings previously in this study guide, figure 14 will show you what they look like. Remember, these couplings are used to join two pieces of conduit.



Rigid Conduit Connected with Coupling



EMT Coupling Indention Type

EMT Coupling Compression Type

Figure 14. Couplings

The compression or split ring coupling is made up of five parts: one body threaded on both ends, two split rings and two end nuts. The nuts are slipped over the ends of the conduit, then the split rings are slipped over the conduit. The conduit is then inserted into the body until the end of the conduit butts up to an internal shoulder. The split ring is pushed to the end of the body and the end nut is threaded onto the body. As the nut is tightened, the split ring is compressed against the conduit causing a secure grip on the conduit. See figure 15.

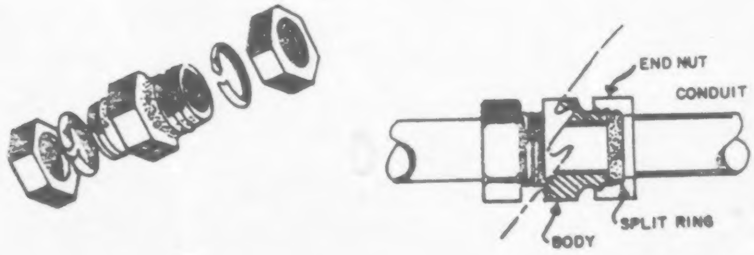


Figure 15. Compression Coupling

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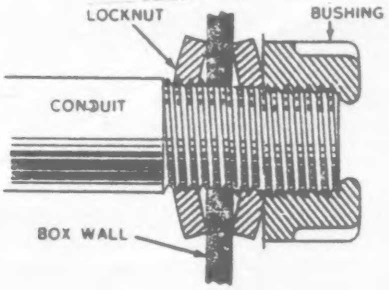
Connectors

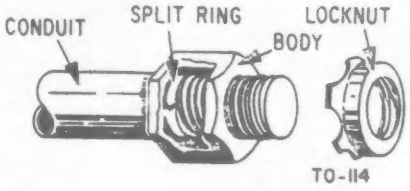
All parts of the electrical circuit must be protected mechanically from the source (panelboard) where the circuit branches (junction box) where the circuit is controlled (switchbox) to where the power is used (duplex, light fixture, etc). In order to fasten this material into the circuit, connectors are used. The type of connector will depend on the type of conduit involved. Changing from one type of conduit to another type of conduit will require a special connector.

Rigid conduit is normally connected to a box by the use of two locknuts, one inside the box and one outside the box as shown in figure 16. A bushing is also used and serves to hold the inside locknut and protects the conductor insulation.

An EMT connector has a compression fitting on one end and a locknut fitting on the other. The compression fitting is attached to the conduit and the locknut is used to attach the connector to the box. Shown in figure 17.


LOCKNUT
BUSHING
CONDUIT
BOX WALL

Fastening Rigid Conduit to a Box
Figure 16


CONDUIT
SPLIT RING
LOCKNUT
BODY
TO-114

EMT Compression Box Connector
Figure 17

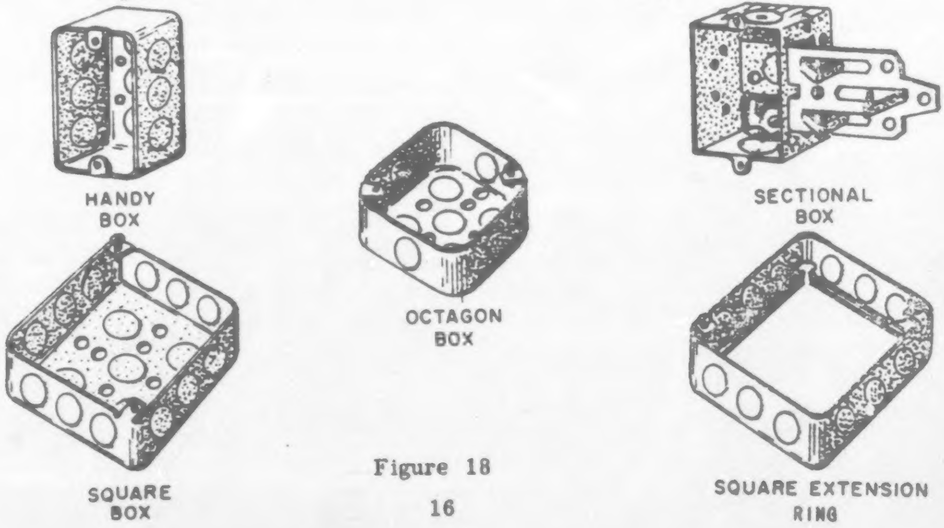

HANDY BOX
SECTIONAL BOX
OCTAGON BOX
SQUARE BOX
SQUARE EXTENSION RING

Figure 18

Boxes

Boxes may be of several shapes, as shown in figure 18, and depths. They are used to protect the device installed in them such as a switch or duplex and to provide space for splices while offering a firm mounting for devices and fixtures. According to Article 370, entitled "Outlet, Switch and Junction Boxes, and Fittings," certain rules have been established concerning the above items. Some of these rules will be discussed in the following paragraphs, however, reference should be made to Article 370 of the NEC.

One of the provisions of Article 370 is that when installing conduit, round boxes shall not be used if locknuts or bushings are installed to the side of the box. Another provision is that boxes or fittings installed in wet locations shall be weatherproof. The heat produced when current flows will limit the number of conductors that can be placed in certain size boxes. Table 370-6(a)(1) through Table 370-6(b) show the numbers and sizes of the conductors and also the dimensions and types of boxes used. Article 370 also indicates that all unused openings, such as knockouts, are to be effectively closed. Boxes shall also be securely and rigidly fastened to the surface to which they are mounted. In completed installations each outlet box shall have a cover installed. Reference is also given to pull and junction boxes. A junction box is used when a conductor must be spliced and continued to other sections of a circuit. A pull box is used in long or hard runs of conduit so the conductors can be pulled to that point and then pulled to the next opening.

Straps

Conduit is secured with conduit straps to the structure. Different sizes and types are used depending on the size of the conduit, type of conduit, and type of structure. Figure 19 shows some examples of conduit straps.

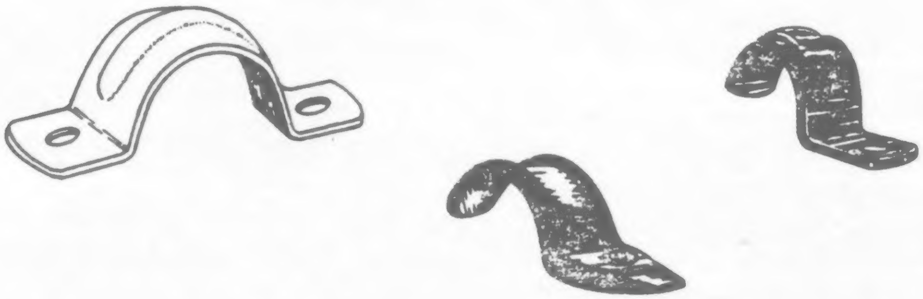


Figure 19. Conduit Straps

Condulets

There are two types of conduit bends. They are factory bends and field bends. Sometimes, because of construction features, it is necessary to have a bend in a conduit system that is closer than a bend that can be made with a bender. It may be necessary to have a pull box due to the amount of bends in a run of conduit. In these cases a condulet would be installed to suit the situation. Condulets are factory made in various shapes to cover different situations. One side will provide an open area to help when pulling in wires. A few of the types are shown in figure 20.

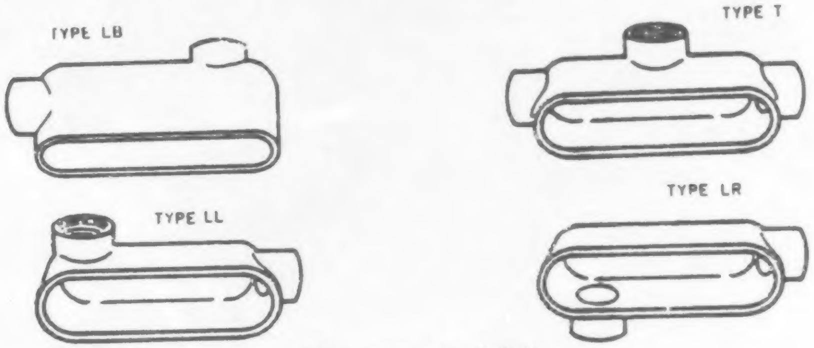


Figure 20. Condulets

TERMINOLOGY

The electrical trade, probably more than any other, is subjected to many terms that are never known except to electricians.

Chapter I. Article 100 of the National Electrical Code contains a large list of these definitions. Several of the more common terms and definitions are included here:

Fitting: An accessory such as a locknut, bushing, or other part of a wiring system which is intended primarily to perform a mechanical rather than electrical function.

Service Raceway: The rigid metal conduit, electrical metallic tubing or other raceway that encloses the service entrance conductors.

Device: A unit of an electrical system which is intended to carry but not utilize electrical energy. Example - switch.

Raceway: Any channel for holding wires, cables or busbars which is designated expressly for, and used solely for, this purpose.

Weatherproof: Weatherproof means so constructed or protected that exposure to the weather will not interfere with successful operation.

Appliance: Utilization equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions, such as clothes washing, air conditioning, food mixing,etc.

Isolated: Means that an object is not readily accessible to persons unless special means for access are used.

Switchboard: A large single panel, frame, or assembly of panels on which are mounted, on the face, back or both, switches, overcurrent and other protective devices, buses and usually instruments.
Switchboards are generally accessible from the rear as well as from the front, and are not intended to be installed in cabinets.

Ventilated: Provided with a means to permit circulation of air sufficient to remove an excess of heat, fumes, or vapors.

Stub: The rise of conduit above a given point. Normally associated with a 90° bend.

Takeup: The amount, in inches, of conduit consumed in the bend.

Parallel: Two lines that if extended forever would not touch or cross. Two lines in the same plane of reference.

Outside-to-Outside: In reference to conduit bends, from the extreme outside edge of the bend to the extreme outside edge of the conduit on the other side of the bend.

Inside Diameter: The distance, in inches or fractions thereof, across the opening of the conduit.

SUMMARY

It is in your best interests to know your tools and how to use them. They will make your job easier and faster and allow you to work more safely.

Being able to identify and use the factory-made materials available will improve your efforts. You cannot decide at any stage of your Air Force electrician career that you know all the materials available as new products are constantly coming on the market.

Correct terminology permits you to define and communicate more exactly in the language of your trade. Study the National Electrical Code chapter on terms and definitions. This should be a continuing study as new terms are constantly being included in the language.

QUESTIONS

1. EMT is cut with a pipe cutter. T F
2. A Device uses electrical energy. T F
3. Rigid conduit over 3/4 inch cannot be threaded. T F
4. EMT and Rigid conduit require different benders T F
5. Burrs on rigid conduit may be removed with a rattail file. T F
6. When installing rigid conduit to a box, a locknut should be used on both sides of the box. T F
7. A hacksaw blade with 32 teeth per inch is satisfactory for EMT conduit. T F
8. A Bushing is used to reduce the size of a hole in an octagon box. T F
9. Rigid conduit is fastened together with a threaded coupling. T F
10. Condulets can be used instead of bends in rigid conduit. T F

REFERENCES

1. TO 32-1-101, Maintenance and Care Handtools
2. AFR 127-101, Ground Safety Accident Prevention Handbook

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CONDUIT WIRING

OBJECTIVE

This study guide will help you identify the different uses of conduit and how they are formed and installed.

INTRODUCTION

Since conduit wiring systems offer the greatest mechanical protection to the circuit, it is considered to be the safest method of wiring. This method of wiring allows more possibility for change and updating of the wiring requirements than most other methods. As with other methods of wiring, conduit wiring systems requirements are covered under the National Electrical Code.

INFORMATION

NATIONAL ELECTRICAL CODE INSTALLATION REQUIREMENTS FOR CONDUIT

As you have already discovered from the previous block of instruction, the National Electrical Code establishes minimum safety requirements for electrical work. This holds true for conduit wiring systems. Chapter 3, "Wiring Methods And Materials," discusses installation procedures and requirements for wiring. This chapter is broken down into articles and paragraphs concerning specific types of material installation.

Rigid Conduit

Chapter 3, Article 346, covers the installation limitations and requirements for rigid metal conduit. You will note that rigid galvanized conduit has the fewest restrictions of any conduit system. Notice that the size of conduit is from 1/2 inch up to 6 inches in diameter.

Electrical Metallic Tubing

Chapter 3, Article 348-1 through 348-14(e), covers the use and installation of EMT. Note that because of the thinner walls of this conduit, special attention must be provided to prevent physical damage during or after installation.

Flexible Conduit

Chapter 3, Article 350-1 through 350-5, covers the use and installations of flexible conduit. Note the restrictions and size limitations.

TYPES OF CONDUIT FIELD BENDS

Conduit installations are normally referred to as "runs" of conduit. A conduit run is the bends and installation of piping from one opening to the next opening. For example, from the panelboard to the first outlet or from the first outlet to the second outlet.

A run of conduit is normally made up of a combination of bends. These combination bends are called offset, back to back, gooseneck, and saddle bends.

Offset

An offset bend is two equal bends in opposite directions. It is used to avoid a part of the structure or to bring the conduit out from the structure to match a knockout in a box or panel. Note in figure 21 after the bends are made the conduit sections on each end of the offset are parallel to each other.

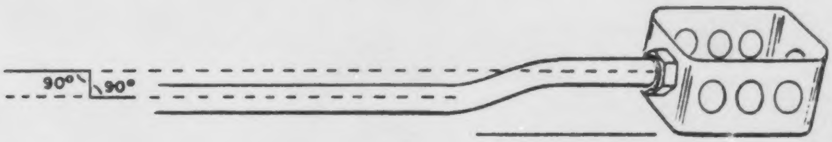

Figure 21. Offset Bend

To make accurate offsets of 2" or more in depth a predetermined distance can be marked on the conduit before making the bends. Table 1 shows how to judge the distance. Because of the radius of the bender, offsets less than 2" in depth, such as the box offset shown in table 1, cannot be calculated as described. The amount of bend for box offsets is merely estimated.

Table 1

Angle of Bends	Constant Multiplier
$22\frac{1}{2}^\circ \times 22\frac{1}{2}^\circ$	2.5
$30^\circ \times 30^\circ$	2.0
$45^\circ \times 45^\circ$	1.5
$60^\circ \times 60^\circ$	1.2
Formula OFFSET DEPTH X CONSTANT MULTIPLIER = DISTANCE BETWEEN BENDS	

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Example: Offset 3" deep with 30° bends.

1. Multiply depth of offset by constant multiplier shown for 30° bends (see table) 3" x 2.0 = 6".
2. Place marks on conduit 6" apart shown in figure 22.
3. Make a 30° bend at each mark.

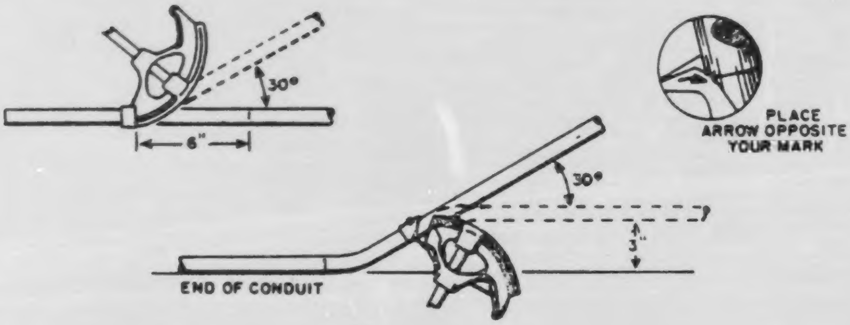

Figure 22

NOTE: Bend with mark on conduit opposite arrow on bender.

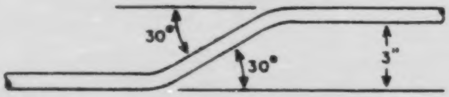

Figure 23

The result is an offset that will clear a 3" obstruction as shown in figure 23.

Back-to-Back

The back-to-back is two opposed 90° bends that reverse the direction in a run of conduit. In making the back-to-back bend the first 90° bend is made with a certain amount of "stub." The length of stub is obtained by marking the desired distance from one end of the conduit and subtracting the takeup. Then place arrow of bender at that point and make a 90° bend. The amount of takeup is determined by the size of conduit shown in table 2.

Table 2

BENDER TAKEUP	90° Stubs
1/2" EMT	5"
3/4" EMT or 1/2" Rigid	6"
1" EMT or 3/4" Rigid	8"
1 1/4" EMT or 1" Rigid	11"

Figure 24 shows how to make a 90° bend with a 10" stub on 1/2" EMT.

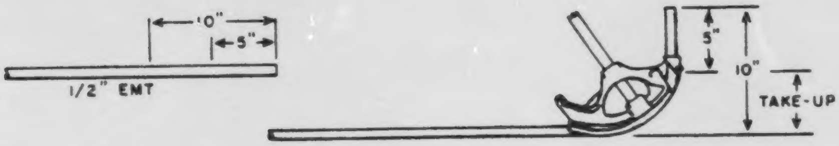

Figure 24

To determine where to place the second bend an outside-to-outside measurement must be taken and marked on the conduit. The bender is then placed on the conduit with the star point symbol on the bender opposite the finish line desired. (The star foretells where the back of the 90° bend will lay.) The 90° bend is then made opposing the first 90° bend as shown in figure 25.

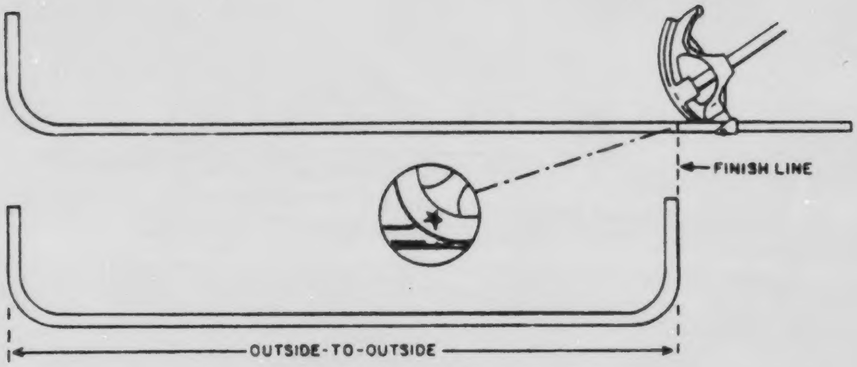

Figure 25

Pipe Saddle

The pipe saddle is used when going from a flat surface over a round obstruction, such as a pipe, and back to the same flat surface. This bend is made using three opposed bends. Figure 26 shows a pipe saddle.

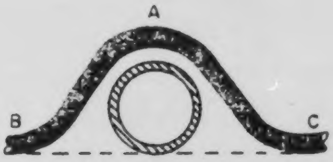

Figure 26. Pipe Saddle

The first bend of the pipe saddle is a 45° bend made at point "A" in figure 26. The star of the bender is placed opposite the point where the conduit will pass over the obstruction. Bends "B" and "C" are 22 1/2° bends opposing the 45° bend. These are made with the arrow of the bender at points 2.5 X diameter of the obstruction on either side of point "A." The distances should be marked on the conduit prior to bending, as illustrated in figure 27.

Example: Pipe Saddle over a 2" diameter pipe.

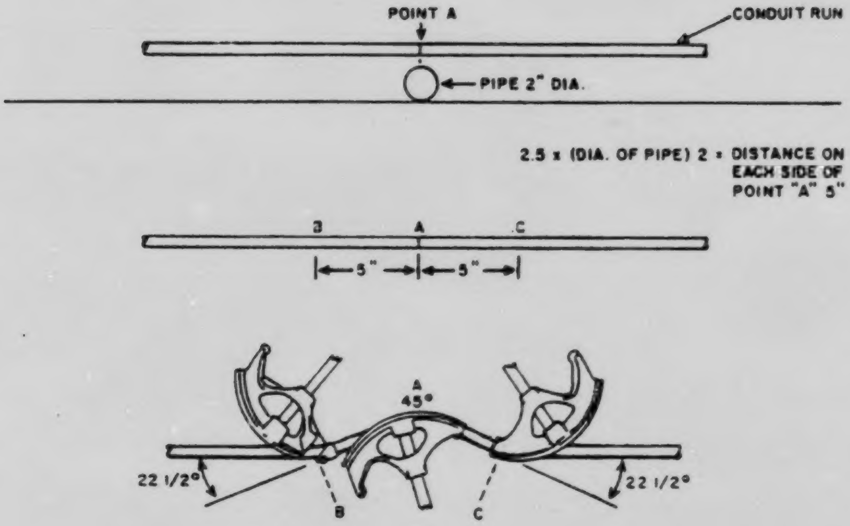
POINT A
CONDUIT RUN
PIPE 2" DIA.
2.5 x (DIA. OF PIPE) 2 = DISTANCE ON EACH SIDE OF POINT "A" 5"
B
A
C
5"
5"
A
45°
22 1/2°
22 1/2°
B
C

Figure 27

Gooseneck

The gooseneck bend consists of one 90° bend and an offset. The gooseneck is generally used when installing an overhead fixture through the ceiling as shown in figure 28.

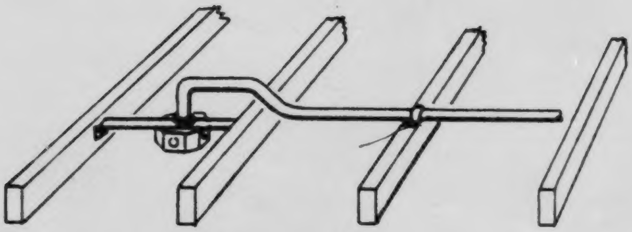

Figure 28. Gooseneck Bend

The 90° bend for the gooseneck, when run on ordinary ceiling joists, should be bent with the shortest possible stub without reducing the inside diameter of the conduit. This reduces the amount of offset that needs to be made and also leaves less conduit above the ceiling joists. The depth of the offset can then be determined by measuring from the top of the ceiling joists, as illustrated in figure 29.

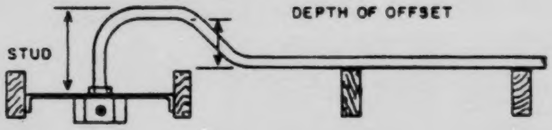

Figure 29.

CONDUIT BENDING

The actual bending of conduit is an art. Like all forms of art, the more often it is practiced correctly, the more proficient the artist becomes. Each type of conduit has its own peculiarities when bends are being formed.

Rigid Conduit

The bends in small rigid conduit are formed with a short throw hook called a "hickey." The hickey does not have reference marks cast in. This requires the operator to perform much more by feel of the work than other benders. When bending rigid conduit the hickey is moved short distances up the conduit in what are called "bites." The length of the bites should be kept uniform to assure a smooth bend of the same radius. See figure 30.

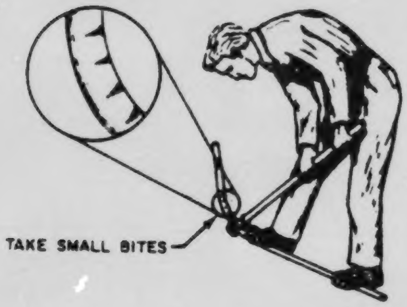

Figure 30. Bending with a Hickey

Because rigid conduit has a thick wall and is difficult to bend, the diameter of rigid conduit that can be bent with a hickey is limited to about one inch. Larger sizes of rigid conduit are formed with hydraulic benders or factory made bends are used.

To assure that the bends are correct a level should be used, if available. If a level is not available, a corner can be used to check a 90° bend. With practice you will develop a feel for the amount of pressure required to bend conduit.

ELECTRICAL METALLIC TUBING (EMT)

EMT is forced with a special bender as previously stated. Each diameter EMT will require a bender of that diameter. All the normal field bends can be made with the bender. The shape of the bender will provide automatically for the proper bend radius. This bend radius is not less than 6 times the internal diameter of the conduit. If used correctly, the bender will help prevent kinking, flatting, or reducing the inside diameter of the conduit.

When possible, the bend will be made on the floor allowing the operator to use the "foot step" as well as the handle in making the bend. See figure 31.

This helps keep the conduit flat and also requires less pressure to complete the bend.

There will be times when it will not be possible to make the bend on the floor. This situation can arise because of a bend already made in the conduit so that the conduit cannot lay flat on the floor. If this happens, the bends can be made "in the air." As you see from figure 32, the bender handle rests on the floor with the bender head up. Extra care is required to keep the bends straight and the handle from slipping on the floor.

EMT conduit will probably be the type conduit you will work with most in your Air Force career. It combines good protection with reasonable cost to provide an excellent system.

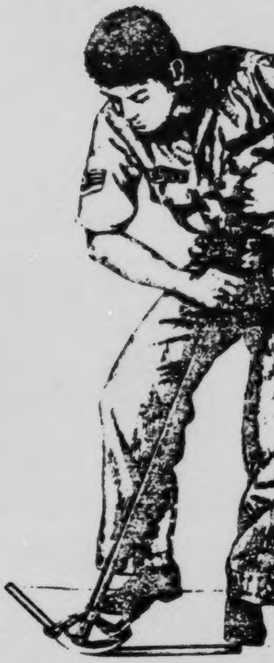

Figure 31. Floor Bend With EMT

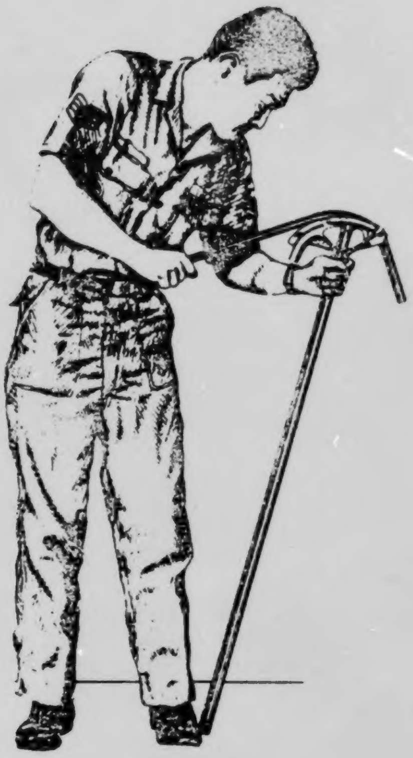

Figure 32

Flexible Conduit (Greenfield)

Flexible conduit will not require a tool for bending as it can be readily shaped with your hands. Flexible conduit may, however, require tying to some support to maintain the desired bends when it is installed.

Flexible conduit must not be used in wet locations. Flexible conduit must be secured by cable clips or pipe straps within 12 inches of the box and then at intervals not to exceed 4 1/2 feet. Flexible conduit is cut to length with a fine-toothed hacksaw. The cut should be made at right angles to the steel ribbon that makes up flexible conduit as shown in figure 33.

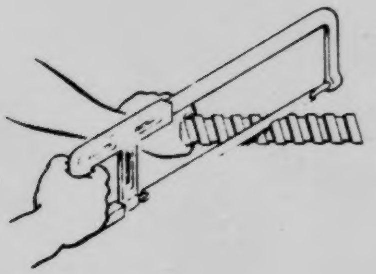

Figure 33. Cutting Flexible Conduit

After the ribbon is cut, grasp the conduit on each side of the cut and twist the conduit. The rough edges should be dressed with a file and a split bushing inserted to protect the conductor insulation as shown in figure 34.

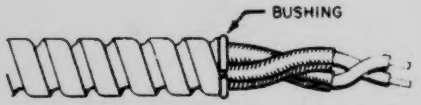

Figure 34. Bushing Installed In Flexible Conduit

THREE-PHASE POWER

You may require three-phase power to operate three-phase motors or other equipment in the building. The power requirements will dictate to a large degree what three-phase power configuration is run to the building. The two basic conditions that would exist would be power only or power and lights.

Figure 35 shows two transformer connections that may be used.

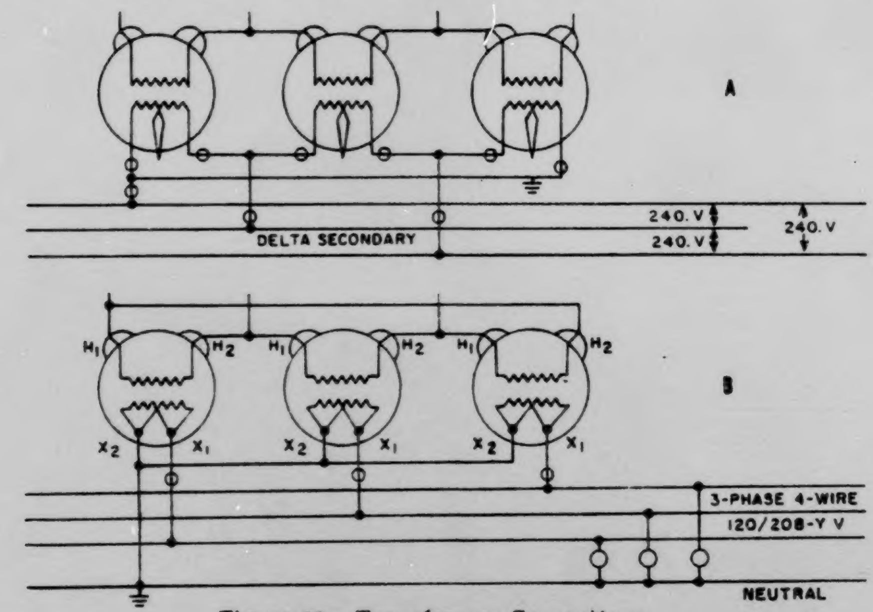
A
240. V
240. V
240. V
DELTA SECONDARY
H1
H2
H1
H2
H1
H2
B
X2
X1
X2
X1
X2
X1
3-PHASE 4-WIRE
120/208-Y V
NEUTRAL

Figure 35. Transformer Connections

Figure 35 A, would be used where only power is needed to operate motors. Only three wires are available and the voltage between them is higher than can be used for a normal lighting circuit; 35 B connection provides a neutral wire so that you will have a lighting circuit or single-phase voltage available if required.

TERMS AND DEFINITIONS

To understand the purposes and installation of a service entrance, you must become familiar with the terms and definitions of the service, service drop, service entrance, and service equipment.

Service

Service is provided by the conductors and equipment for delivery of energy from the electrical supply system to the wiring system of the premises served.

Service Drop

Service drop is made in the overhead service conductors from the last pole or other aerial support to the first point of attachment to the service entrance conductors at the building or other structures.

Service Entrance

Service entrance is the service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop. A typical, single-phase service entrance using conduit is shown in figure 36.

Service Equipment

Service equipment consists of a circuit breaker or switch and fuses, and their accessories. They are located near the point of entrance to a building and are intended to constitute the main control and means of cutoff for the supply to that building.

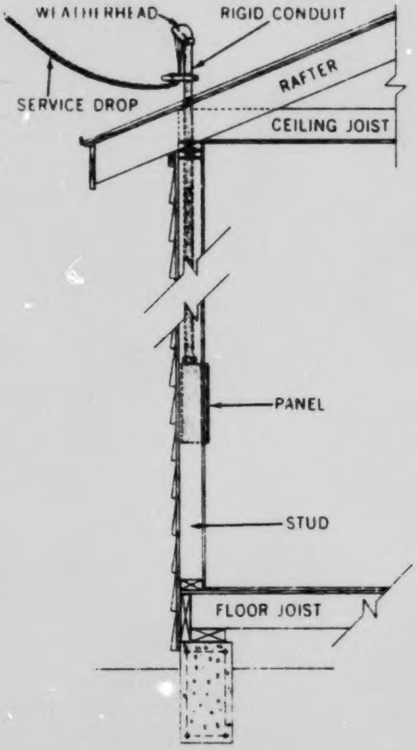

Figure 36. Service Entrance Installation

ELECTRICAL POWER SYSTEMS

The service entrance is attached to the service drop and consists of a weatherhead (service cap and conductors) which are connected to the service equipment.

The service equipment can be in a panel by itself or it can be included in a panelboard containing the branch circuit protective devices. The service equipment is provided to connect or disconnect the power supplied to the fuses or breakers and the branch circuits. The fuses or breakers are included in the system to protect the equipment and circuit from damage in case of an overload or short, in accordance with NEC Article 240.

Branch circuits extend from the protective devices and provide power in the different rooms or areas of the building. It is best to hold current flow to a minimum on the identified or neutral conductor. To do this, the unidentified or hot conductors should carry the same amount of current flow. This is referred to as balancing circuits.

INSTALLATION OF THE SERVICE ENTRANCE

The service entrance will be of the overhead or underground type. In most modern construction the service entrance will be made in conduit.

In some cases the design engineer provides all the necessary information for installation of the service entrance; however, if this information is not provided, you may locate it in Article 230 of the NEC. The service to the building should be centrally located. This will help prevent low voltage at the ends of the building caused by long conductor runs. The service entrance that you install will be in conduit. Figure 37 identifies the parts of your service entrance.

Service Cap (Weatherhead)

The weatherhead is made up of a ceramic or a bakelite separator washer and a screw type metal cover. It is attached by threads to the conduit mast and normally will be at least 10 feet above the ground. The weatherhead is used to prevent water from entering the conduit and damaging the conductor insulation.

Conduit

The conduit will generally be of a rigid type, cut to correct length to provide proper clearance, threaded on both ends and of sufficient size to carry the required size conductor.

Entrance Ell

The entrance ell is also called a condulet. It is used as a pull box and to make a sharp 90° angle from the conduit to the panelboard by the use of a nipple.

Nipple

The nipple is a piece of conduit of the correct length to go through the outer wall and connect the condulet to the panelboard by locknuts.

Conductors

The conductors should be of sufficient size to provide the correct amperage to the building. They must be long enough to extend from the panelboard through the weatherhead plus about 3 feet to form a drip loop. All conductors should be installed at one time.

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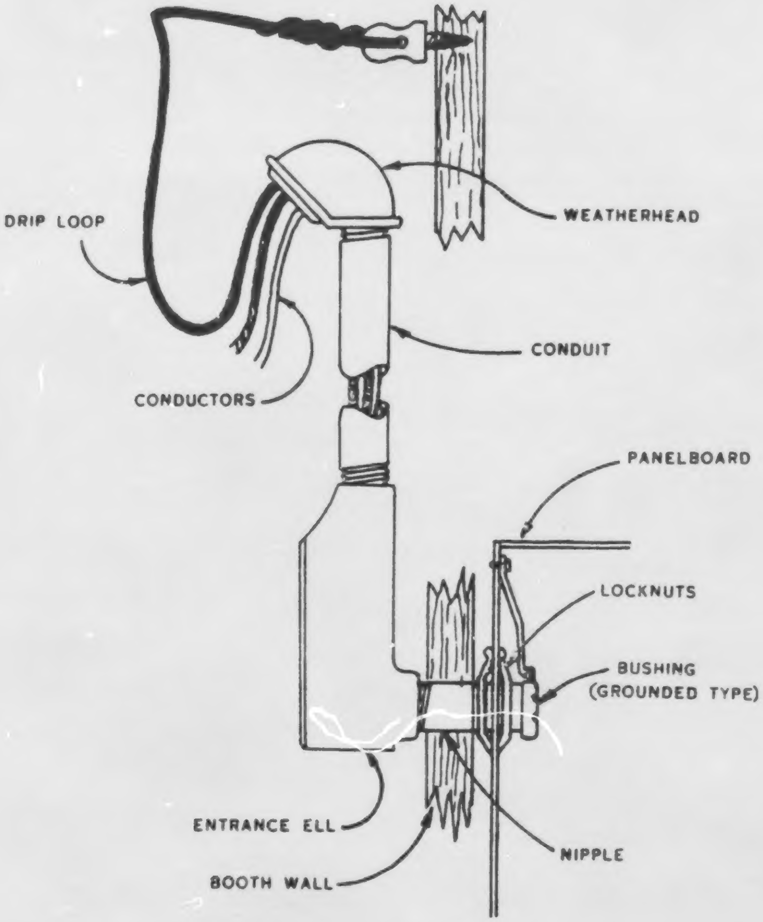
DRIP LOOP
WEATHERHEAD
CONDUIT
CONDUCTORS
PANELBOARD
LOCKNUTS
BUSHING
(GROUNDED TYPE)
ENTRANCE ELL
NIPPLE
BOOTH WALL

Figure 37. Service Entrance Components

Assembly of Components

Attach the conduit to the weatherhead and condulet. Then attach the nipple to the condulet. Insert the nipple into the previously drilled hole through the outer wall. Attach the conduit to the building with a strap within 3 feet of every box or fitting and 10 feet thereafter. Then put a locknut on the nipple outside and inside the panelboard. When this second locknut is tightened, the panelboard is secured to the nipple. Then attach the panelboard to the wall with screws. The conductors are installed and a grounding bushing is screwed onto the end of the nipple inside the panelboard. This bushing is to prevent damage to the conductor insulation and to ground the conduit system. The conductors are now connected to the panelboard as shown in figure 38.

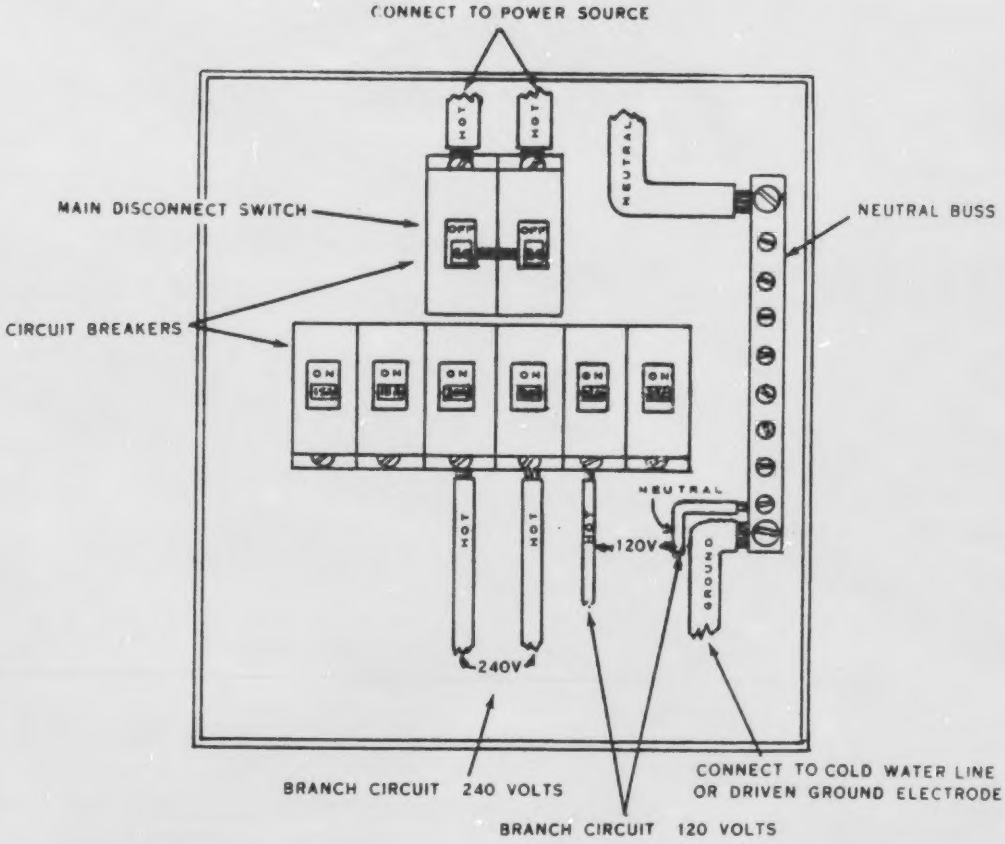
CONNECT TO POWER SOURCE
HOT
HOT
NEUTRAL
MAIN DISCONNECT SWITCH
NEUTRAL BUSS
OFF
OFF
CIRCUIT BREAKERS
ON
ON
ON
ON
ON
ON
NEUTRAL
HOT
HOT
HOT
120V
GROUNDING
240V
BRANCH CIRCUIT 240 VOLTS
CONNECT TO COLD WATER LINE
OR DRIVEN GROUND ELECTRODE
BRANCH CIRCUIT 120 VOLTS

Figure 38. Panelboard

Grounding

The ground clamp should be made of the same material as that to which it is attached. If an iron water pipe is used for ground, then use an iron clamp; if copper is used, use a copper clamp. This is done to hold down electrolytic action which can deteriorate the ground or ground wire. The loss of a ground would result in the system becoming very dangerous.

SUMMARY

Requirements for conduit wiring can be found in the National Electrical Code.

Rigid conduit up to one inch can be formed with a hickey, is connected by threads, cut with a hacksaw or pipe cutter, and reamed before installing. EMT is cut with a fine-tooth hacksaw, then reamed and formed with a special EMT bender.

Flexible conduit is a specialized conduit, highly restricted to use, that should be cut with a hacksaw at right angles with the steel ribbon that makes up the conduit. The cut must be dressed and a split bushing should be used.

NOTE: See articles 346, 348, 350, 300, and 215 of the NEC for additional information.

Three-Phase Services will be either three-wire or four-wire, depending on the use to be made of the power in the building.

QUESTIONS

1. Name three types of conduit.
2. What is the maximum size of rigid conduit?
3. How does rigid conduit differ from water pipe?
4. How is the diameter of conduit determined?
5. If possible, how should EMT be formed?
6. What is the minimum bend radius for EMT?
7. Name two uses of flexible conduit.
8. What should be used at the ends of flexible conduit to protect the conductors?
9. What is a service drop? What is a service entrance?
10. What two things should be considered when establishing three-phase service requirements?

REFERENCES

1. AFM 91-17, Electrical - Interior Facilities
2. AFP 85-1, Electrical Facilities Safe Practices Handbook
3. National Electrical Code
4. Electrical Trades Blueprint Reading
5. NFPA Handbook of the NEC
6. Practical Wiring
7. Electrical Code Diagrams, Volumes I and II

CIRCUIT EXTENSIONS

OBJECTIVE

This study guide is to help you understand the types, purpose, and installation requirements for circuit extensions in accordance with the National Electrical Code.

INTRODUCTION

Building plans and builders try to anticipate the needs and requirements of the occupant for electrical power. Changes in use of the building, new or additional equipment, or reorganization of personnel may require additional or relocated outlets. Because of building construction or the temporary nature of the new requirements, it may not be feasible to run new branch circuits within the finished walls of the building. A system for providing neat, safe electrical outlets has been provided under the rules of the NEC. This system is called circuit extensions. In this study guide we will discuss two types of circuit extensions.

INFORMATION

SURFACE METAL RACEWAY

Where appearance is a primary factor, surface metal raceway is used. This raceway is finished with a baked-on enamel finish that blends with or complements the wall finish and is meant to be used only as an exposed circuit extension. Circuit extensions in surface metal raceway must be continuous from outlet to outlet. It may not be used for concealed work or where subjected to corrosive fumes. Surface metal raceway comes in various sizes and with factory-made fittings such as pull boxes, junction boxes, switchboxes, receptacle outlets socket outlets, elbows, couplings, bushings, straps, hangers, adapters, and the like. Figure 39 shows a typical surface metal raceway installation.

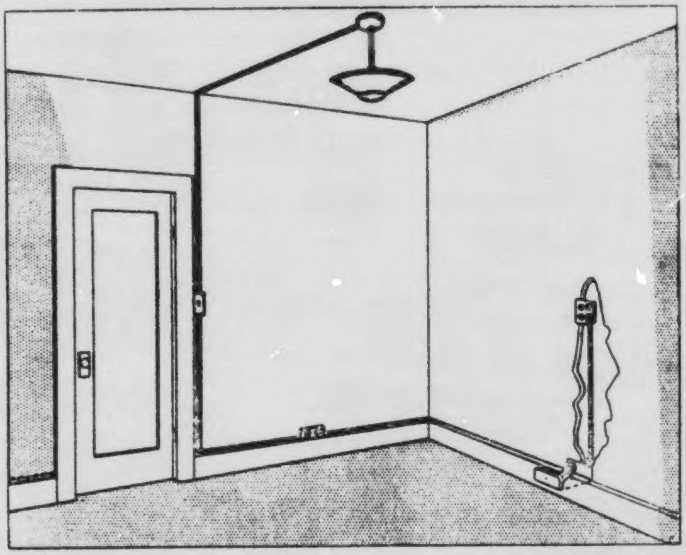

Figure 39. Typical Surface Metal Raceway Installation

INSTALLATION OF SURFACE METAL RACEWAY

Starting at the existing outlet, fasten a blank extension adapter over the existing outlet box with machine screws. Figure 40 shows an extension adapter.

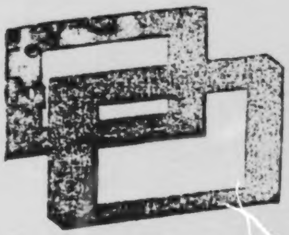

Figure 40. Extension Adapter

Align the run of metal raceway and install the other required bases for tees, corners, switches, or outlet boxes. These bases should be installed with flathead screws or toggle bolts to prevent insulation damage to the conductors when they are installed. Figure 41 shows the installation of the basic supporting units for a surface metal raceway circuit.

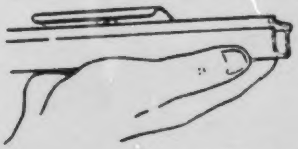

Figure 41. Supporting Clip

The surface metal raceway must be supported at least each 4 1/2 feet. Couplings are used to fasten the raceway to surface on which it is being installed. Couple the base of the fittings to the raceway by slipping the tongue of the fitting under the base of the raceway. Using a pair of pliers, remove twistouts from the covers, then snap on screw covers to bases of the metal raceway. Snap on elbow and connection covers and install conductors. In the case of inside elbows, it may be necessary to use pulleys and a fish tape to install the conductors before the elbow covers are installed. See figure 42. Other installation requirements are found in Article 352 of NEC.

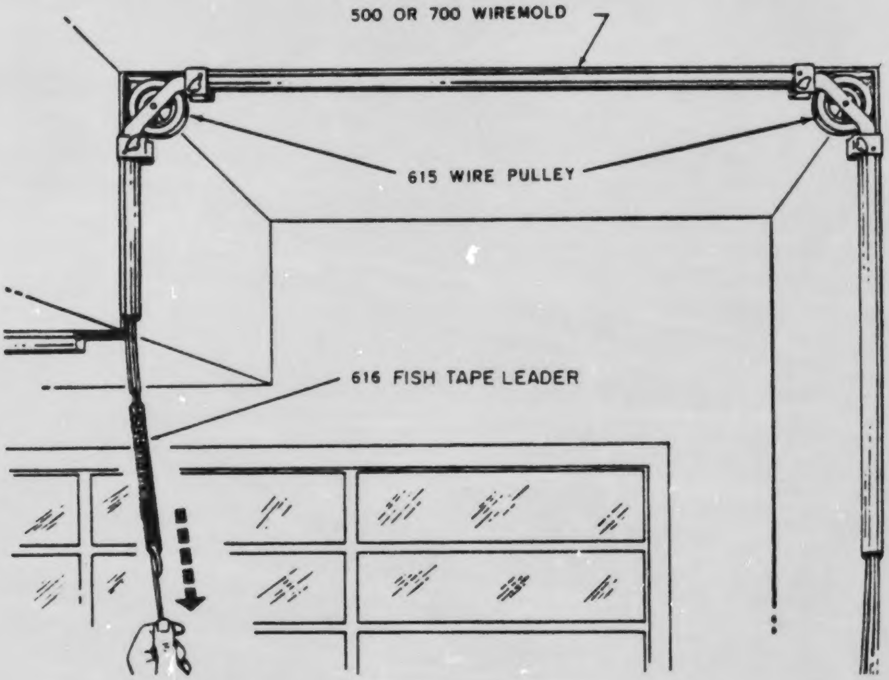

Figure 42. Fishing Conductors Through Surface Metal Raceway

Conductors Allowed in Raceway

The number and size of conductors in surface metal raceway will be determined by the size and design of the raceway. Table 1 will show the number of conductors that may be installed in various sizes and types of surface metal raceway.

TRADE NAME	MANUFACTURER'S DES. NO.	NUMBER OF WIRES			
		14	12	10	8
Wiremold	200	3	3		
	500	5	4	3	2
	700	8	6	5	3
	1000	10	10	8	8
	1500	4	4		
	2100	6	6		
National Metal Molding	022 & 222	2	2		
	044 & 333	4	4	3	3
	111	2			

Table 1. Number of Conductors Used in Raceways

Installing Switches and Receptacles

The installation of switches and receptacles in surface metal raceway will be governed by the same rules of the National Electrical Code that apply to conduit installation.

CONDUIT CIRCUIT EXTENSIONS

Conduit circuit extensions differ from surface metal raceway circuits in that a conduit circuit extension may be either exposed or concealed. The conduit circuit extension may be in rigid, EMT or flexible conduit, installed in the same manner as a regular branch circuit and is subject to the same NEC rules.

SUMMARY

Surface metal raceway circuit extensions are restricted to resident and office space installation. They are designed to provide either additional or relocation of outlets. They are usually constructed of a material that will blend into the overall decor of the room. Surface metal raceway will provide mechanical protection. Factory-made fittings and connections for surface metal raceway provide for almost any installation situation. Surface metal raceway may be painted to blend with any surroundings. Conduit circuit extensions may be either exposed or concealed and are made of regular rigid, EMT, or flexible conduit.

QUESTIONS

1. What is the purpose of circuit extensions?
2. Where may surface metal raceway circuit extensions be installed?
3. What is the maximum voltage for a surface metal raceway extension?
4. What governs the number of conductors that may be installed in surface metal raceway?
5. Why are circuit extensions sometimes necessary?
6. What holds metal raceway to a wall?
7. How are conductors installed in metal raceway?
8. How may a conduit circuit extension differ from nonmetallic or suface metal raceway circuits?

REFERENCES

1. National Electrical Code
2. Blueprint Reading
3. NFPA Handbook of NEC
4. Practical Wiring
5. Electrical Code Diagrams, Volumes I and II

LOW-VOLTAGE CIRCUITS

OBJECTIVE

This study guide is designed to familiarize you with special circuit utilization, operation, and installation.

INTRODUCTION

The voltages which you have encountered so far in dealing with residential and office wiring have been the standard voltages of 120 or 240 volts. These voltages are usually the same as those supplied by the distribution system from the distribution transformer. Unless the duplex outlet in a building is especially marked, you would expect to find 120 volts. However, certain types of equipment do not operate on this much voltage. The reason is that lower voltages are safer to handle. Circuits which operate on voltages lower than 120 volts are usually referred to as low-voltage circuits. Some of the more important low-voltage circuits are needed for doorbell systems and fire alarm systems. This study guide will deal with the low-voltage doorbell circuit.

INFORMATION

LOW-VOLTAGE DOORBELL SYSTEM

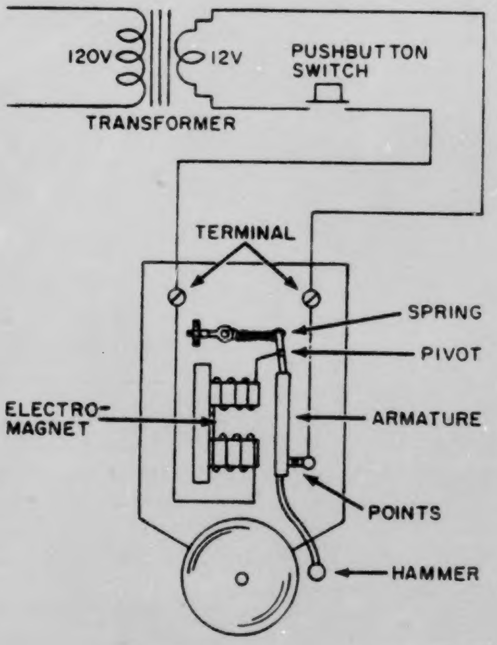

Figure 43.

Probably the simplest low-voltage circuit that you will encounter is the circuit in an ordinary doorbell system. The doorbell circuit has a stepdown transformer for reducing the voltage; bells, chimes, or buzzers for signaling; a pushbutton switch for completing the circuit; and wires to connect the components together. Figure 43 is a wiring diagram of a typical doorbell circuit.

In operation the circuit is simple. 120 volts is applied to the primary side of the transformer continuously. The transformer reduces the voltage to 12 volts for the operation of the bell. When you press the pushbutton switch, the low-voltage current travels to the terminal, through the electromagnet, through the contact points and back to the other terminal and returns to the transformer.

The electromagnet pulls the armature down, breaking the circuit. The armature is then moved by a spring to its former position, closing the contact points and again energizing the circuit. Rapid repetition of the cycle causes the arm to vibrate and ring the bell. The loudness of the bell is controlled by adjusting the spring tension.

A buzzer works on the principle of the bell. However, chimes do not interrupt the circuit as do buzzers and bells. The electromagnet pulls a plunger which strikes a plate, and the plate produces the chiming sound. The circuit is broken when the button is released, and the plunger is returned by spring action and strikes the plate. Two-station chimes have two solenoids. One solenoid acts like the one described with the single plunger, and the second plunger hits only one striker plate and produces a single tone.

Circuits for bell, buzzers, and chimes can be controlled from more than one location by paralleling the pushbutton switches. More than one bell or buzzer can be controlled from one location by paralleling the bells or buzzers. The conductors used in low voltage of the circuit are usually two #18 AWG insulated copper conductors twisted together. Be careful not to overload the transformer.

SUMMARY

Some circuits require special voltages. Special voltage circuits should be marked. A doorbell circuit is normally a low voltage circuit. A stepdown transformer is used to reduce normal 120 volts to 12 volts to operate the doorbell system. The major parts of the doorbell system are: A transformer, a pushbutton switch, a signaling device and associated wiring. More than one pushbutton may be used by paralleling the switches. Normally number 18 AWG insulated copper wire is used to install a doorbell circuit.

QUESTIONS

1. Why do some circuits require a low voltage?
2. What should be done to any duplex outlet that is furnishing voltage different from the normal 120 volts?
3. What is the purpose of the stepdown transformer in a doorbell system?
4. What is the purpose of the electromagnet in the doorbell?
5. How is the loudness of the bell controlled?

REFERENCES

1. NEC
2. Electric Trades Blueprint Reading, R. C. Mullin 1969 Edition
3. NFPA Handbook of NEC, Frank Stetka
4. Practical Wiring, H. P. Richter
5. Electrical Code Diagrams, B. Z. Segall

TROUBLESHOOTING CONDUIT CIRCUITS

OBJECTIVE

This study guide is to help you become familiar with the types of troubles you will find in conduit wiring systems and the procedures for locating and correcting them.

INTRODUCTION

Troubles in an electrical system are generally caused by careless construction, lack of maintenance, misuse of the sytem, thoughtless and careless acts of the occupants, and age of the system. One of your responsibilities as an electrician will be to troubleshoot electrical circuit systems.

Since troubleshooting of an electrical circuit can vary with the type of system, voltage applied, use of the system and many, many other variables, this study guide cannot cover all possibilities.

INFORMATION

TROUBLESHOOTING CONDUIT CIRCUITS

As you learned in Block II there were three basic circuit problems: (1) opens, (2) shorts, and (3) grounds. These problems remain basically the same no matter what the type of wiring installation. In conduit systems many of these troubles are caused by improper installation of conductors in the conduit. As an example, insulation stripped or conductors broken. Because of the physical protection conduit allows, the system is relatively free of trouble after it is installed. The other conditions that cause breakdown, other than improper installation, are heat, age, and moisture. Procedures for troubleshooting a conduit wiring system are the same as for an NM cable system except that a conduit run is a grounded system. When called on to troubleshoot any wiring system, information from the person that reported the trouble will often save you valuable time and trouble.

SUMMARY

Troubles are classified as opens, shorts, and grounds. An open is a circuit that is not complete, or has no continuity. A short is where two conductors of different potential are touching, and a ground is when a conductor is making contact with a motor frame, appliance, conduit, etc. A logical sequence and common sense will be a key to how long it will take to troubleshoot a circuit.

185

APPLIANCE MAINTENANCE

OBJECTIVE

A thorough study of this text will help you become familiar with wiring diagrams and specifications for electrical kitchen equipment, methods of testing and isolating electrical malfunctions and determining the extent of necessary repair.

INTRODUCTION

This text covers the electric heating and cooking equipment ordinarily used in domestic quarters, hospitals, and dining halls on Air Force installations. Although the types of equipment used may vary the basic operating parts of these appliances such as the heating elements; switches, motors, and thermostats are the same. There are three basic types of kitchen equipment; element heated, motor driven, and a combination of both motor driven and element heated.

INFORMATION

APPLIANCES

Ranges

Surface elements of ranges cook food by conduction of heat from the surface unit to the utensil. Each surface unit is controlled by a switch having three or more heat positions.

Ovens

Electric ovens cook food by radiated and convected heat and are thermostatically controlled to maintain even temperatures. In addition to the thermostatic controls, most ovens have a lower and an upper switch-controlled heating element to obtain various heat combinations.

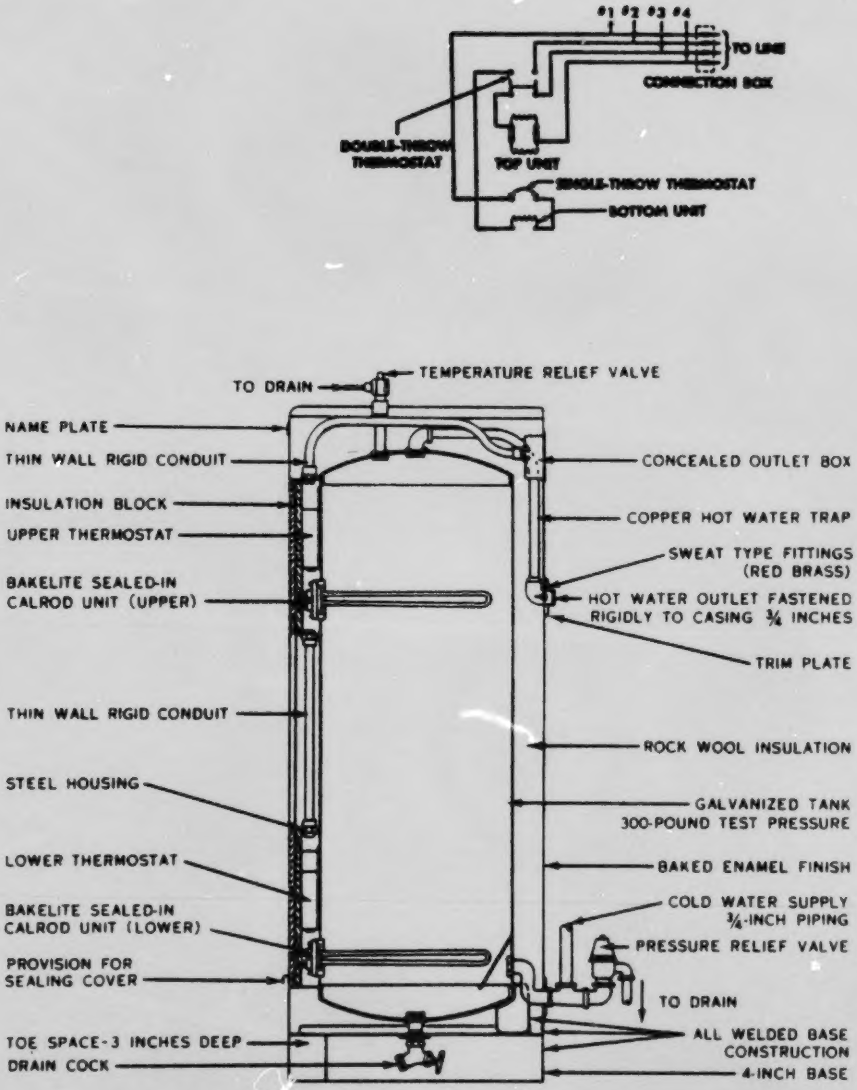
#1 #2 #3 #4
TO LINE
CONNECTION BOX
DOUBLE-THROW THERMOSTAT
TOP UNIT
SINGLE-THROW THERMOSTAT
BOTTOM UNIT
TO DRAIN
TEMPERATURE RELIEF VALVE
NAME PLATE
THIN WALL RIGID CONDUIT
INSULATION BLOCK
UPPER THERMOSTAT
BAKELITE SEALED-IN CALROD UNIT (UPPER)
THIN WALL RIGID CONDUIT
STEEL HOUSING
LOWER THERMOSTAT
BAKELITE SEALED-IN CALROD UNIT (LOWER)
PROVISION FOR SEALING COVER
TOE SPACE-3 INCHES DEEP
DRAIN COCK
CONCEALED OUTLET BOX
COPPER HOT WATER TRAP
SWEAT TYPE FITTINGS (RED BRASS)
HOT WATER OUTLET FASTENED RIGIDLY TO CASING ¾ INCHES
TRIM PLATE
ROCK WOOL INSULATION
GALVANIZED TANK 300-POUND TEST PRESSURE
BAKED ENAMEL FINISH
COLD WATER SUPPLY ¾-INCH PIPING
PRESSURE RELIEF VALVE
TO DRAIN
ALL WELDED BASE CONSTRUCTION
4-INCH BASE

Figure 44. Twin Unit Water Heater and Wiring Diagram

Water Heaters

Electric water heaters have a storage tank, one or two heating elements, insulation, shell, and one or two temperature controls. The heating elements deliver heat directly to the water and each element has a thermostat usually located just above it, as illustrated in figure 44. The average temperature setting of the control is 150°F, the most desirable water temperature for all purposes.

Toasters

Both domestic and commercial toasters have a toasting chamber with heating elements which heat the bread by radiation. Domestic toasters are usually operated manually by a switch or time mechanism; commercial toasters are usually operated by a motor-driven chain conveyor.

Coffee Urn

Coffee urns have two compartments, an inner coffee brewer and an outer hot water jacket. The immersion type heating element heats the water in the jacket which in turn heats the brewer. Heat is regulated by a thermostat or a three-heat switch providing low, medium, and high temperatures.

CONNECTIONS

Kitchen equipment is connected to a source of power by one of two methods: permanent and temporary. Temporary connections are made by means of a flexible cord attached to a male plug and connected or plugged into a wall outlet. A temporary connection is usually made on low voltage, portable equipment. Permanent connections are made by wiring the appliance directly to a junction box of the power circuit. A permanent connection is usually made on large, high voltage, stationary equipment.

Appliances usually have manuals or information sheets showing wiring connections and diagrams.

ELEMENTS

Heating elements are of the open and enclosed types. The element usually consists of a high resistance nichrome wire.

Types of Open Elements

The rod-and-coil type heating element, as shown in figure 45, is used in bake ovens, roasters, and space heaters.

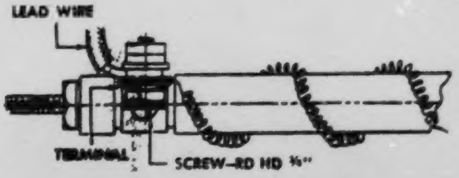

Figure 45. Rod-and-Coil Heating Element

Suspended coil heating elements are supported by porcelain insulators and used in small ovens and space heaters.

Ribbon type heating elements, usually wrapped around a mica insulator, are ordinarily used in small appliances such as irons, toasters, small heaters, etc.

Types of Enclosed elements

Enclosed tubular units of the surface cooking type, as shown in figure 46, are used on domestic ranges and some commercial ranges. The resistance wire is surrounded by an insulating powder and covered by a copper tube.

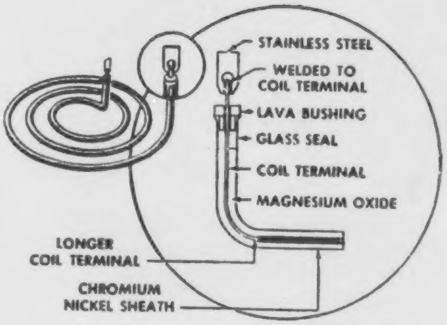

Figure 46. Construction of Typical Tubular Heating Element

Types of Enclosed Elements

The immersion type unit, as shown in figure 47, is ordinarily used in water heaters, commercial fry kettles, and sterilizers. Immersion type elements must be constantly submerged in liquid to prevent damage.

The cast-in units have the tubular coils described above cast in iron. They are designed to withstand the abuse of heavy cooking utensils. Heavy duty ranges are equipped with cast-in units.

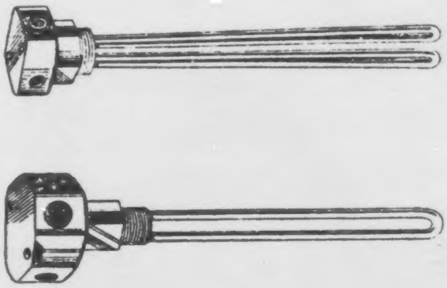

Figure 47. Immersion Type Unit

MOTORS

Appliances that require ordinary alternating current motors for their operation such as meat slicers, potato peelers, dishwashers, grinders, etc., are numerous on Air Force installations. Often an appliance is element heated and also requires a motor for operation.

CONTROLS

Switches

The toggle switch with an ON-OFF position is used to make and break the electric circuit on many appliances. Rotary switches have fast make-and-break action. The current is interrupted ahead of the make-and-break of the switch contacts, eliminating the usual pitting and burning of contacts. The rotary switch requires very little maintenance.

On some large appliances such as 220-volt coffee urns and ranges a magnetic switch is used to control power to the heating element.

Temperature Controls

The basic function of all temperature controls, for heating and cooking equipment, is turning the current on and off as required to maintain the desired temperature.

The bimetallic blade control is operated by the expanding and contracting effect caused by heating two pieces of dissimilar metals welded together. A similar type is used in such appliances as irons and portable coffee makers.

Two other types of temperature controls are the helix control and hydraulic control. The helix control is operated by a coiled thermostatic metal that coils and uncoils when heat is applied, operating a switch to make and break the electric current. The hydraulic control is operated by expansion and contraction of a liquid in a bulb causing diaphragm or bellows to activate the switch mechanism of the control.

Timers

The timer is used to automatically control a circuit to an appliance or give a warning to the operator that a predetermined time has lapsed. Figure 48 shows a typical wiring diagram of an electric range single-pole oven timer.

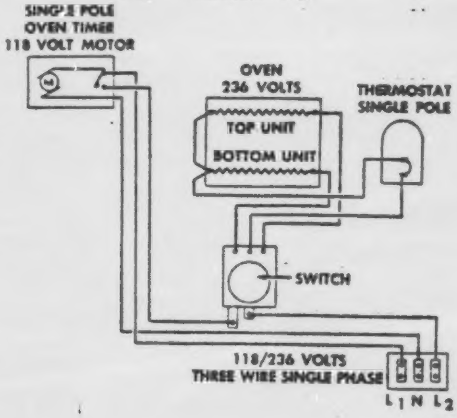

Figure 48. Typical Oven Timer Wiring Diagram

TROUBLESHOOTING AND REPAIR

A defective appliance should first be inspected visually. Multimeters are indispensable devices in testing electrical circuits of appliances if the visual inspection fails to analyze the trouble.

Motor-Driven Appliances

The three main sources of trouble in motor-driven appliances are the power connections, switches and motor field windings. Check all power connections for a bad male plug, broken or shorted flexible cord and loose or dirty connections. Check the switch for a broken case, making and breaking of the contacts, and loose and dirty connections.

Check the motor for opens, shorts, and grounds if it is inoperative. Tighten all loose connections. Clean all dirty connections. If the motor cannot be readily repaired, install a substitute or replacement motor.

Heating Elements

Check heating elements for continuity by using a multimeter. Check all connections and switches for continuity. If an open heating element becomes oxidized or brittle, replace the entire element. If the element is fairly new or a replacement is not readily available, repair it by one of the following methods. Repairs are only temporary and replacements must be ordered, to replace the repaired element.

Braze with silver solder the broken ends of the heating element wire using a suitable flux as shown in figure 49.

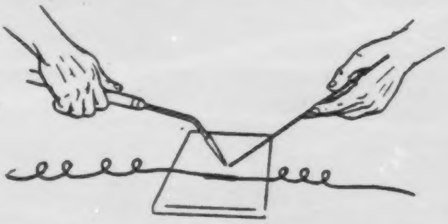

Figure 49. Brazing Broken Ends of Heating Element Wires

Insert broken ends in a split-washer as shown in figure 50 and pound flat, making sure that a solid connection is obtained.

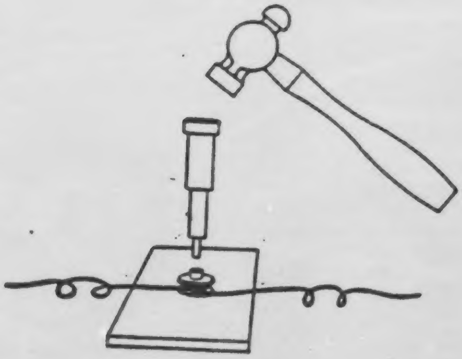

Figure 50. Split-Washer Method

Nichrome sleeves are available to fasten the ends together. The sleeve should be flattened out to insure a solid connection as shown in figure 51.

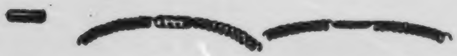

Figure 51. Showing Use of Nichrome Sleeves

Inclosed units can sometimes be repaired by stripping the sheath of the heating unit and welding or brazing a new terminal to the lead.

Switches and Controls

Check switches and controls for making and breaking of contact with ohmmeter. If the switch is ON, the ohmmeter should read "0."

New switches are usually so inexpensive that repairing an old one is not economical. The contacts may be reformed as a temporary measure to insure a positive contact for completing the electric circuit. Lubricating the contacts and spring mechanism with nonoxide grease reactivates switch operation.

Repair of the bimetallic blade control is limited to an adjustment in the temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested. Temperature of equipment should be tested by a reliable temperature tester or a good thermometer.

Repair of the helix control is limited to adjustment of temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested. If the control cannot be adjusted, the complete control assembly must be replaced.

Timers

If a timer fails to operate, use the following procedures to locate the trouble.

1. Test electric circuit for blown fuse.

2. Check for friction between hands of timer and timer crystal.

3. Check all wire connections. To repair the inoperative electric timer, perform the following:

    a. Replace blown fuses with fuse of proper rating.

    b. If rotor is inoperative replace complete rotor.

    c. If field coil is burned out, replace complete coil assembly.

    d. Repair timer switch assembly by cleaning contacts or reforming the contact arm to insure positive contact. If contacts show excessive wear, replace switch assembly.

e. If hands of timer are binding on crystal, re-form hands to eliminate the condition.

f. Check all connections at back of timer for positive contact to insure a completed circuit.

SUMMARY

Electrical kitchen equipment is connected to a source of power by the permanent or temporary method. Temporary connections are usually made on low voltage, portable equipment. Permanent connections are made by wiring the appliance directly to a junction box of the power circuit.

Heating elements are of the open and enclosed types. The element usually consists of a high resistance nichrome wire.

Most kitchen appliances have ordinary toggle switches to turn on the electrical current to heat the element or start a motor; however, some appliances employ a rotary switch that has a fast make-and-break contact action. Most heating and cooking equipment have temperature controls to maintain the desired temperature. Timers are used to control appliances at a predetermined time.

The first inspection of an appliance should be made visually. Motor-driven appliance troubles are usually located in the switch, connections, or the motor field windings. If a motor cannot be readily repaired, replace it.

Heating elements can be repaired by brazing, using a split washer or nichrome sleeve if it is not oxidized or brittle; otherwise, it should be replaced.

Switches are usually so inexpensive that repairing an old one is not economical. On most temperature controls the temperature setting can be adjusted to agree with the actual temperature of the appliance.

Wiring on the interior of a heating appliance has a fireproof insulation such as asbestos.

QUESTIONS

1. What is a heating element?
2. Name two types of elements.
3. What two kinds of power hookups are used on mess equipment?
4. Name three kinds of switches used on mess equipment.
5. What is meant by motor-driven, element-heated, and combination appliances?

6. Give an example of a motor-driven, element-heated appliance.

7. What equipment is used in testing an appliance?

8. List three methods of repairing a heating element.

9. What is the first step in troubleshooting an appliance?

REFERENCE

AFM 85-17, Maintenance and Operation of Electric Plants and Systems

WORKBOOKS 3ABR54230-1-III-1 thru 8

Department of Civil Engineering Training

Electrician

Block III

CONDUIT WIRING

August 1975

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

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ELECTRICIAN

(Days 21 - 30)

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This supersedes SGs and WBs 3ABR54230-1-III-1 thru 8, July 1973

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-1
August 1975

PUBLICATIONS

OBJECTIVE

This unit of instruction is to provide guidance in the use of technical orders, and standard and commercial publications.

EQUIPMENT AND SUPPLIES	Basis of Issue
SW 3ABR54230-1-III-1	1/student
Limited Technical Order File	8/students
Project Cards	1/student

PROCEDURE

Project 1

1. Complete the following sentences or supply information as requested.

a. AF publications are divided into 2 classes, ____________________ and ____________________, and each class contains several categories.

b. List the 4 categories of publications and give examples if applicable.

(1) ____________________

(a) ____________________

(b) ____________________

(c) ____________________

(d) ____________________

(2) ____________________

(a) ____________________

(b) ____________________

(c) ____________________

(3) ____________________

(4) ____________________

c. The types of TOs are as follows:

(1) ____________________________________

(2) ____________________________________

(3) ____________________________________

(4) ____________________________________

(5) ____________________________________

(6) ____________________________________

(7) ____________________________________

d. Detailed information for the operation, usage, maintenance, inspection, installation and overhaul of equipment can be found in ____________________ ________________________.

e. ____________________________Tech Orders provide instructions for accomplishing or recording one-time changes.

f. The types of Time Compliance Tech Orders are as follows:

(1) ________________________

(2) ________________________

(3) ________________________

(4) ________________________

(5) ________________________

g. Methods and Procedures Type Tech Orders provide information and Instructions for ________________ and ______________personnel.

h. Why are Index Publications needed?

i. The types of Index Publications are:

(1) ________________________

(2) ________________________

(3) ________________________

(4) ________________________

2. From the Card No ______________ given to you from your instructor, complete the following chart.

PROBLEM NO	ANSWER
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

3. From the Card No _____________ given to your from your instructor, complete the chart below.

PROBLEM NO	ANSWER
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

4. Locate TO title in the indexes from another card assigned to you by your instructor.

Card Number ____________________

PROBLEM NO	TO TITLE
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

5. Have instructor check workbook and sign.

Checked by ____________________
(Instructor)

REFERENCES

1. AFR 0-2
2. TO 00-5-1
3. National Electrical Code

200

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-1-2
August 1975

POWER TOOLS

OBJECTIVE

When you have completed this workbook you should be able to:

1. Index and drill holes in a piece of metal stock using a drill press.
2. Dress metal stock using a bench grinder.
3. Drill holes in metal stock using a portable drill.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-III-2	1/student
Drill Press	8/students
Drill Vise	8/students
Bench Grinder	8/students
C-Clamp	8/students
Portable Electrical Drill	2/students
Safety Goggles	1/student
Handtools	1/student
Metal Stock	1/student
Assorted Twist Drills	1/student

PROCEDURES

Project 1

You are to perform this project step by step. The equipment you will be using demands respect. It can be very dangerous unless used properly. The instructor should be consulted as indicated.

Step one

The instructor will issue you a piece of flat stock. Put on your safety goggles, button your collar and sleeves. Use a center punch and hammer to mark the center of the stock. Have your instructor check your work.

____
(Instructor)

Step two

1. Position the stock in the drill vise and tighten the vise securely.
2. Have the instructor check the drill press to assure proper speed.

Step three

1. Select a twist bit of the size specified by the instructor ____________________.
2. Secure the bit in the chuck using the chuck key.
3. Set the proper drill depth by operating the spindle handle down to where the bit tip is barely past the stock and adjust the stop nuts to that point.
4. Center the index mark under the bit by lowering the bit and moving the vise until the two points coincide. Lock the vise to the table with a C clamp.

Step four

1. Plug in the drill press but DO NOT turn it on.
2. Have the instructor check your setup ____________________________________.

Step five

Read all of the instructions on this step before beginning to drill.

1. Start the drill press.
2. Use light, steady pressure.
3. Raise the bit after the first light cut to assure you are drilling the index mark.
4. Back off pressure when you feel the bit go through the stock.
5. Stop the drill.

Project 2

To provide you with information on what safety checks to perform before and after using the electric bench grinder, and also to give the operating instructions. You are to dress the edges of the metal stock by grinding on the bench grinder. Use these steps.

Step one, Safety Checks

1. Remove all jewelry while working on or around electrical operated machines.
2. Keep area floor clean and dry.
3. Observe all safety precautions.
4. Keep all loose clothing away from wheel.

Step two, Preparation for Operation

1. Check for loose or frayed wiring in power cord to grinding machine.
2. Face shields are not damaged.
3. Safety goggles are available.
4. Cooling water is available if grinding stock is overheated.
5. Check the wheel clamp nuts, which secure the grinding wheels on the rotor shaft, for tightness.
6. Check position of the tool rests in reference to the grinding wheels to make sure that they do not touch the wheels. The tool rests will not be used more than one-eighth inch from the grinding wheel. If necessary, loosen the hex-head capscrews securing the tool rests to the wheel guards and reorient the tool rests. Tighten the hex-head capscrews.
7. Loosen the hex-head capscrews securing the eyeshields to the wheel guards and position the shields as close as possible to the grinding wheels, but not touching the wheels. Tighten screws.
8. Check to insure that the power source is correct and that the ground connection is secure.
9. Put eye goggles on.
10. After the operation, make sure the wheels have stopped rotating before leaving the grinder.
11. Have the instructor check setup ________________________________.
(Signature)

Step three

Operating Instructions

Place the toggle switch in the ON position. Hold the item to be ground firmly on the tool rest and against the grinding abrasive wheel. Slowly move item back and forth on the wheel with steady, even pressure. Do not hold the item in one spot on the grinding wheel or apply excessive pressure. Keeping the item stationary on the wheel will cause the wheel to be worn down unevenly. Applying the item to the wheel with excessive pressure will result in the item being burnt and discolored. Use the coarse grain wheel for heavy work which requires the removal of a considerable amount of metal. Use the fine grain wheel for light work and when a smooth finish is required.

Step four

Shutdown procedure

1. Remove grinding stock from tool rest.
2. Turn off power switch.

Step .five

Postoperative check.

1. Insure that power cord is unplugged and stored.
2. Area is cleaned of grinding waste material.
3. Grinding wheel is serviceable and not cracked.
4. Have instructor check the work and sign this worksheet ____________________.
(Signature)

Project 3

Follow this project step by step. CAUTION: Portable drills can be dangerous if abused or misused. Use care when operating.

Step .one

The instructor will issue you metal stock. Locate and index the point to be drilled. Have your instructor check the work ____________________________.
(Instructor)

Step two

1. Clamp the stock in a vise. Put on your goggles. Button your collar and assure that no loose clothing can catch in the work.
2. Select the correct twist drill size as indicated by your instructor ______________.
(Size)
3. Place twist drill in the drill chuck and tighten with a chuck key.
4. Plug in portable drill. DO NOT OPERATE UNTIL TOLD TO DO SO. Call your instructor ______________________.
(Instructor)

Step three

Read all instructions before you start this step of the project.

1. Align the twist drill tip with the index mark.
2. Start the drill and engage lightly to the metal stock and make a light cut.
3. Stop the drill and assure that you are cutting on the index mark.
4. Start the drill, drill the metal stock using moderate pressure.
5. When you feel the drill bit going through the metal reduce the pressure.
6. When the drill has penetrated the metal, withdraw the drill bit and turn off the drill. Unplug the drill and remove the drill bit.
7. Have instructor check your work __________________________.
(Instructor)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-3
August 1975

CONDUIT TOOLS, TERMINOLOGY, AND MATERIAL

OBJECTIVE

When you have completed this workbook you will be able to:

1. List the name and use of conduit tools.
2. List the definition to conduit terms.
3. List the name and use of conduit materials.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-III-3	1/student

PROCEDURES

Project 1

1. Match the terms listed on the following page with the definition by putting the corresponding numbers in the blanks. Use the NEC.

TERMS	DEFINITIONS
____a. Connector	1. Rigid metal conduit, electrical metallic tubing, or other raceway, that encloses the service entrance conductors
____b. Fitting	2. An assembly of panels containing over-current devices
____c. Service raceway	3. A unit of an electrical system which is intended to carry but not utilize electric energy
____d. Device	4. A channel for holding wires or busbars
____e. Raceway	5. An accessory such as a locknut, bushing, or other part of a wiring system which is intended primarily to perform a mechanical rather than an electrical function
____f. Weatherproof	6. Thermal protection
____g. Appliance	7. A device which establishes contact between two conductors without use of solder
____h. Isolated	8. An object not readily accessible to persons unless special means for access are used
____i. Switchboard	9. Provided with a means to permit circulation of air sufficient to remove an excess of heat, fumes, or vapors
____j. Ventilated	10. Protected from exposure from the weather
	11. Utilization equipment

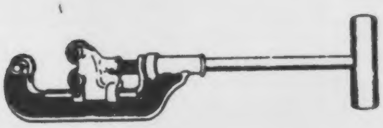
2. Have instructor check work and sign.

Checked by ______________________________
(Instructor)

Project 2

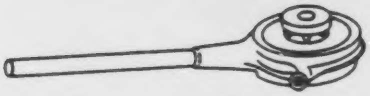
INSTRUCTIONS: Fill in the name and use of each tool illustrated below.

1.



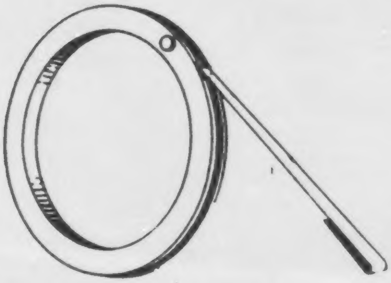
Name ______________________
Use ______________________
____

2.



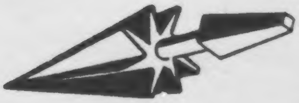
Name ______________________
Use ______________________
____

3.



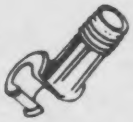
Name ______________________
Use ______________________
____

4.



Name ______________________
Use ______________________
____

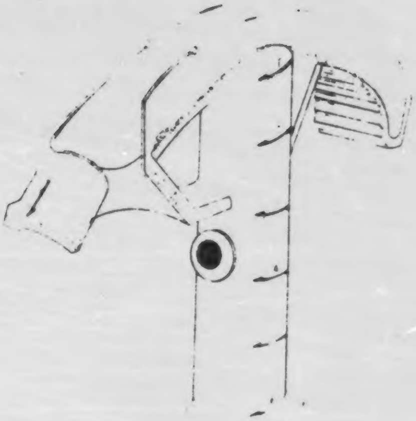
5.



Name ______________________
Use ______________________
____

207

6.

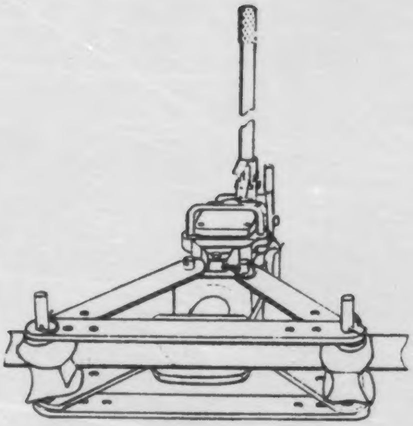


Name ______________________

Use ______________________

____

7.

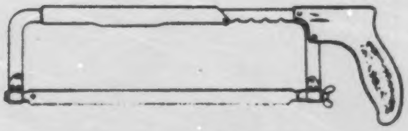


Name ______________________

Use ______________________

____

8.

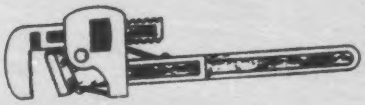


Name ______________________

Use ______________________

____

9.

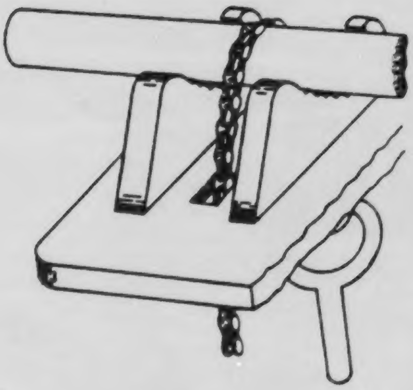


Name ______________________

Use ______________________

____

10.

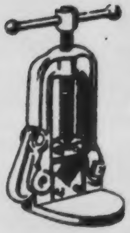


Name ____________________

Use ____________________

____

11.



Name ____________________

Use ____________________

____

12. Have instructor check work and sign.

Checked by ____________________
(Instructor)

Project 3

1. After EMT (electrical metallic tubing) is cut, it must be reamed to prevent damage to the conductor insulation. The tool most commonly used for this purpose is the ______________________________.

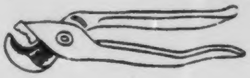
2. When locknuts are used to fasten EMT to a box, the locknuts are tightened with

______________________________.

3. When connecting two pieces of EMT together, the proper handtools to use are

______________________________.

4. The handtool pictured is called ____________.
When working with conduit they are used to ____________



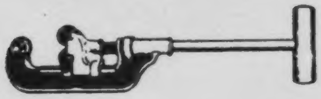
______________________________.

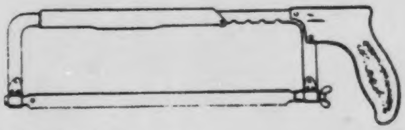
5. From the tools pictured below, select the proper tool for cutting EMT.

____

For cutting rigid conduit. ______________________________

For cutting SMR (surface metal raceway) ______________________________

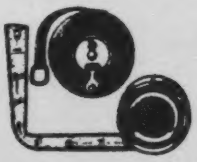


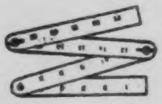


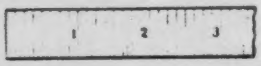
6. The best tool for forming terminal loops on conductors are ____________

______________________________.

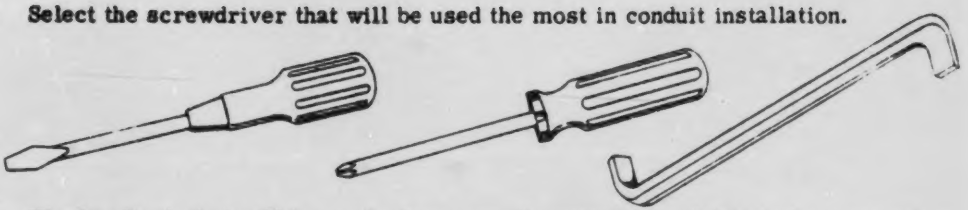
7. From the illustrations below, select the measuring tool most commonly used in conduit installation.







8. **Select the screwdriver that will be used the most in conduit installation.**



9. **The handtool that will be used when a small amount of metal is to be removed is the______________________________.**

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-4
August 1975

CONDUIT WIRING

OBJECTIVE

When you have completed this workbook you will be able to:

1. Complete statements pertaining to conduit cut, ream, thread, and bend rigid conduit; cut, ream and bend electrical metallic tubing.
2. Install a single-phase conduit service entrance.
3. Install a ceiling light, single-pole switch, and duplex outlet.
4. Install a ceiling light controlled by two three-way switches.
5. Add a four-way switch to control a light from three positions.
6. Install a fused disconnect to a main panel.
7. Install a 220 VAC receptacle.

EQUIPMENT AND SUPPLIES	Basis of Issue
WB 3ABR54230-1-III-4	1/student
National Electrical Code Book	1/student
Pipe Vise	1/student
Handtool Set	1/student
Conduit Tools	1/student
Wiring Booth	1/student
Materials (Misc)	1/student
Hickey Bender	1/student
EMT Benders	1/student
Fish Tape	1/student

PROCEDURE

Project 1

1. Using the NEC complete the following statements.
2. Article 346 of the NEC is LABELED __________ __________ __________.
3. The minimum size of rigid conduit is ____________________.
4. All cut ends of conduit shall be ____________________.
5. The purpose of a bushing is to ____________________.
6. The maximum degrees of bends in a run is ______________________________.

7. Rigid conduit will be supported _________ feet from each box and every ________ feet thereafter.

8. Article 348 of the NEC is LABELED ________ __________ _________.

9. Article 350 of the NEC is LABELED _________ _________ __________.

10. You have just completed some statements using the NEC, it is your guide for electrical wiring.

Project 2

This project will be accomplished step by step. Have your instructor check where indicated.

Step one

Select a piece of 1/2-inch rigid conduit and mark it for bending an eight-inch stub.

Have your instructor check your work ______________________________.
(Instructor)

Step two

Make a 90° bend in the conduit without kinking, flattening,or reducing the inside diameter.

Step three

Using the pipe vise and pipe cutter, cut the conduit 12 inches behind the bend.

Step four

Use the conduit reamer and ream the conduit.

Step five

1. Select the correct pipe die and stock.
2. Assemble the stock and die.
3. Slip the die over the conduit as shown in figure 1.

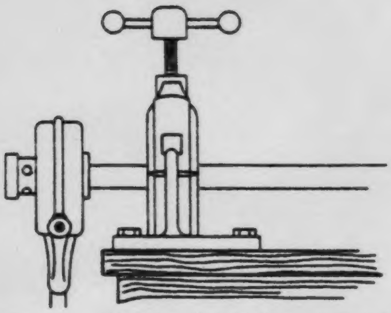


Figure 1. Slipping Stock Over Conduit

4. Turn stock with one hand and apply forward pressure against stock with other hand until die begins to cut threads as shown in figure 2.

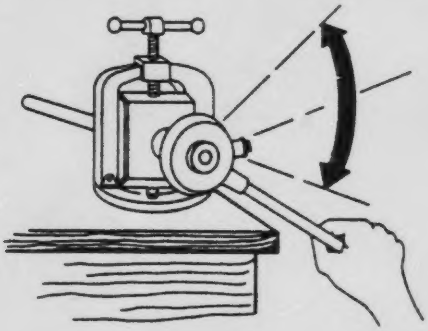


Figure 2. Turn Stock Applying Forward Pressure

CAUTION: During cutting, apply thread-cutting oil to threads, die, and conduit every two or three turns, as shown in figure 3. This will prevent damage to pipe threader.

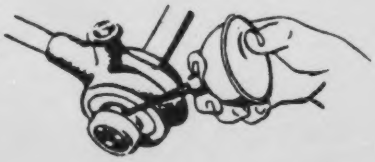


Figure 3. Apply Oil to Threads

5. When the threads are cut to the correct length, reverse the stock ratchet latch and turn the die off the conduit.

   CAUTION: Remove the conduit from the vise.

Step six

Call your instructor to check your work ______________________________
Instructor

Step seven

Clean the area and store the tools. Return the unused conduit to the stack.

Project 3

Follow this project step by step. Call the instructor as indicated.

Step one

1. Select 1/2-inch EMT conduit and correct EMT bender.
2. Mark the conduit to provide a 10-inch stub when completed.
3. Have the instructor check your marks ______________________________
   Instructor

Step two

1. Position the bender and make a 90° bend in the conduit without kinking, flattening, or reducing the inside diameter.
2. Check your bend to assure a 90° bend.

Step three

1. Using the pipe vise and a fine toothed hacksaw, cut the conduit 14 inches behind the bend.
2. Ream the conduit using either a reamer, pliers or a rattail file.

Step four

Remove the conduit from the vise, clean the area, store the unused conduit. Clean and store handtools. Have the instructor check your work and sign this work

project ______________________________
(Instructor)

Project 4

Procedures for bending a pipe saddle to conform to installation requirements.

Step one

Cut and ream one piece of 1/2-inch EMT five-feet long.

Step two

Mark conduit 22 inches from one end.

Step three

From the 22-inch mark make a mark 2 1/2 times height of object to be crossed (2 1/2 x 3 = 7 1/2 inches) on each side (right and left). Make these marks all around conduit.

Step four

Using a 1/2-inch EMT bender, place the 22-inch mark exactly over the top point of the star.

Step five

Using steady pressure, bend the conduit until the bottom lines up with the 45 degree mark.

Step six

Have the instructor check your work.

Step seven

With the bend inverted and placed in front of bender, line the 7 1/2-inch mark on the tip of the arrow.

Step eight

Using steady pressure, bend the conduit until the bottom aligns with the 22 1/2-degree mark on the bender.

Step nine

Remove conduit and turn it around so that all bends are placed in front of bender. Place the second 7 1/2-inch mark on tip of arrow.

Step ten

Align the conduit so that the crown of the 45-degree bend is down and perfectly vertical.

Step eleven

Using steady pressure, bend the conduit until the bottom lines up with the 22 1/2-degree mark on the bender.

Step twelve

Remove conduit from bender and check with the conduit placed over the 3-inch object. It should clear object, and both ends should be flat on floor. If object is cleared and ends point up there is more than 22 1/2 degrees. If ends do not lay flat on the floor, there is not enough in the 22 1/2 degrees. If there is not enough to clear the object, more 45-degree bend is necessary.

Step thirteen

Clean up the area and store equipment.

Checked by ______________________
(Instructor)

Project 5

Procedures for bending a gooseneck bend to conform with installation requirements.

Step one

Cut and ream 1 piece of 1/2" EMT 5 feet long.

Step two

From one end of the conduit, measure and mark the length of the stub (8" in this case).

Step three

From the stub length measure back toward end of conduit and mark the amount of takeup required by the bender (5" for 1/2" EMT). You now have a mark 3" and 8" from the end of the conduit. The second mark (5" from the first mark) should be made completely around the conduit.

Step four

With the conduit on the floor, place the 1/2" EMT bender over it so the handle is in the air and the conduit is in the groove of the bender.

Step five

Align the tip of the arrow on the bender with the second mark you make on the conduit.

Step six

Place one foot on the conduit approximately 18 inches from the bender and the other foot on the heel of the bender and press firmly while drawing the bender handle toward the floor until the end of the conduit is bent vertical (90^{o}) to the floor.

Step seven

With the bender removed, measure from the floor to the tip of the vertical piece of conduit. See figure 4. This should measure 8" plus or minus 1/4". Have instructor check this work ______________________________
(Instructor)

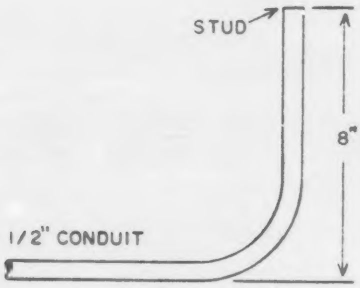


Figure 4

Step eight

Lay the conduit flat on the floor and measure approximately 8" from the end containing the bend toward the long end of the conduit and mark around the conduit. See figure 5.

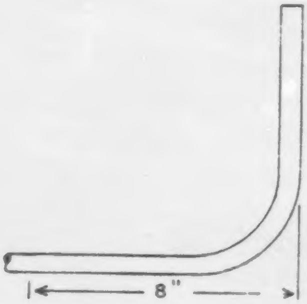


Figure 5

Step nine

For a 5" offset measure (1.5 x 5 = 7.5) 7.5" from the 8" mark just made and mark around the conduit.

Step ten

With the handle of the bender on the floor, place the conduit in the groove with the stub in front of the bender and pointed toward the floor. Using the handle of the bender as a guide, align the conduit for bending.

Step eleven

Move conduit until the first mark aligns with the arrow tip.

Step twelve

With steady pressure, bend the conduit down until you have a 45° bend.

Step thirteen

Move the bends already made forward out of the bender until the arrow on the bender is opposite the second mark.

Step fourteen

Turn the conduit until the stub is pointing up. Align this stub vertically by sighting down the conduit.

Step fifteen

Apply steady pressure and bend the conduit to the 45° mark on the bender. The straight portions should now be parallel.

Step sixteen

After checking your work have it examined by the instructor ____________________
(Instructor)

Step seventeen

Clean up area and store equipment.

Project 6

You are to complete this project in steps. Read the instructions carefully. Be sure to have your instructor check your work where indicated before proceeding.

Step one

Observe the drawing in figure 6. You are to install a service entrance. Make a bill of the materials you will require. Have the instructor check your bill of materials

before proceeding ______________________________
(Instructor)

Step two

Assemble the service entrance. Have the instructor check your assembly

____
Instructor

Step three

Install the service entrance components. Have the instructor check your work

____
Instructor

Step four

Connect the service entrance. Have your instructor check your work

____
Instructor

NOTE: DO NOT apply power until told to do so by your instructor.

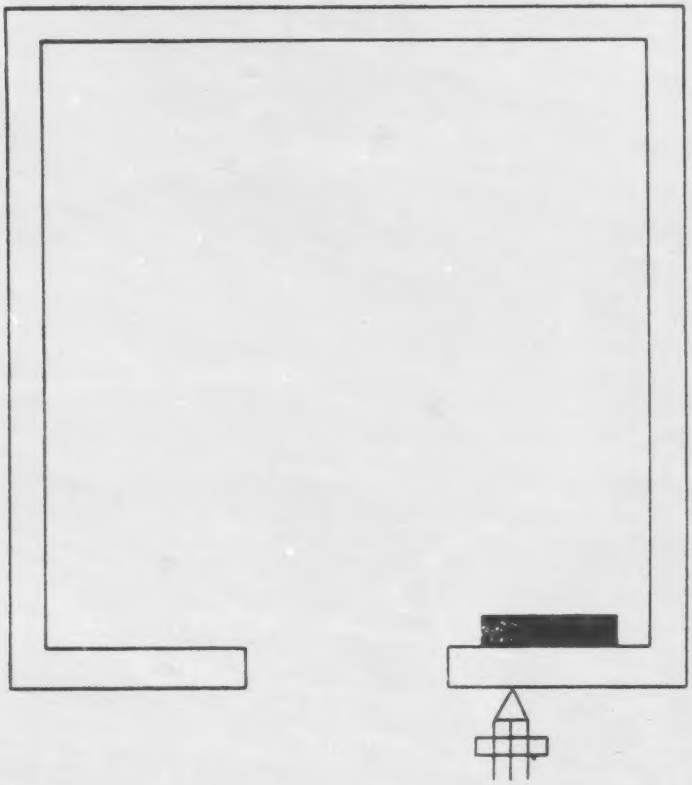


Figure 6. Installation of Service Entrance

NOTES:

1. Service will be 120/240 volts 10.
2. Disconnect will be installed at predrilled hole.
3. Disconnect will be bonded.
4. Ground will be connected to ground electrode.

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Project 7

Follow this project step by step. Observe all safety precautions. Call the instructor when indicated.

Step one

1. Study the blueprint drawing for this project, figure 7.
2. Make a list of the tools and materials that you will need to complete this job.

TOOLS	MATERIALS

3. Have your instructor check your list ______________________________
(Instructor)

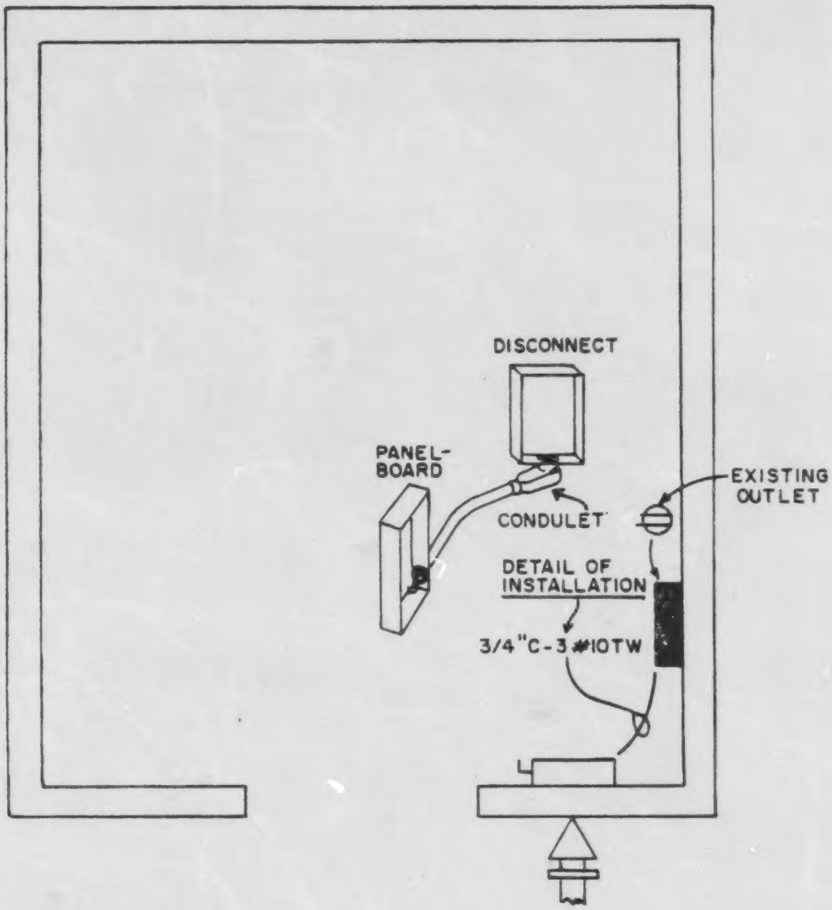

DISCONNECT
PANEL-BOARD
EXISTING OUTLET
CONDULET
DETAIL OF INSTALLATION
3/4"C-3 #10TW

Figure 7. **Panelboard Installation**

NOTES:

1. Service entrance and disconnect are existing.
2. Panelboard will be 1Ø 120/240 volt.
3. Panelboard will be surface mounted on existing plywood finish.
4. Conduit run will be parallel to the floor.

Figure 8. Existing Outlet to be Hooked Up After Panel is Installed

Step two

1. Locate your circuit breaker panel. This panel should be level and firmly secured to the structure so that the conduit run will be parallel with the floor.

2. Measure the distance from the main to the circuit breaker panel and determine the amount of EMT conduit required.

Step three

1. Select your conduit 3/4" EMT.

2. Measure and mark the conduit to provide for all required bends in the run of conduit.

Step four

1. Make your required bends for the conduit run.

2. Cut the conduit to length.

3. Ream the conduit.

Step five

1. Select the correct fitting to secure the panels together and to secure the conduit to the structure.

2. Assemble the fittings to the conduit and install the conduit run.

3. Secure the panels together and the conduit to the structure.

Step six

1. Select the correct conductors for the circuit.

2. Cut and install the conductors.

3. Connect the conductors in the panels.

4. Hook up the existing outlet.

5. Have your instructor inspect your installation and sign your workbook.

____
(Instructor)

Project 8

Complete this project step by step. Call the instructor where indicated. Observe safety at all times.

Step one

Study the blueprint provided with this project, figure 8. Draw the equipment and supplies you will require from supply. List the equipment or supplies that are not available. Have your instructor check list

______________________ (Instructor)

Step two

Install the boxes as indicated on the blueprint. Check to see that they are (1) level, (2) properly secured to the structure, (3) set to the correct depth, and (4) set at the correct height.

Step three

Using 1/2" EMT, bend and cut the conduit to fit the runs. (You may refer back to previous work projects if you need to.)

Step four

Use conduit fittings and assemble the conduit runs to the boxes.

Step five

Secure the conduit to the structure.

Step six

Refer to your blueprint and make a single line drawing of the circuits to be installed below. Color code your drawing. Have your instructor check the drawing

______________________ (Instructor)

Step seven

Select the correct size and color conductors and pull the conductors into the conduit.

Step eight

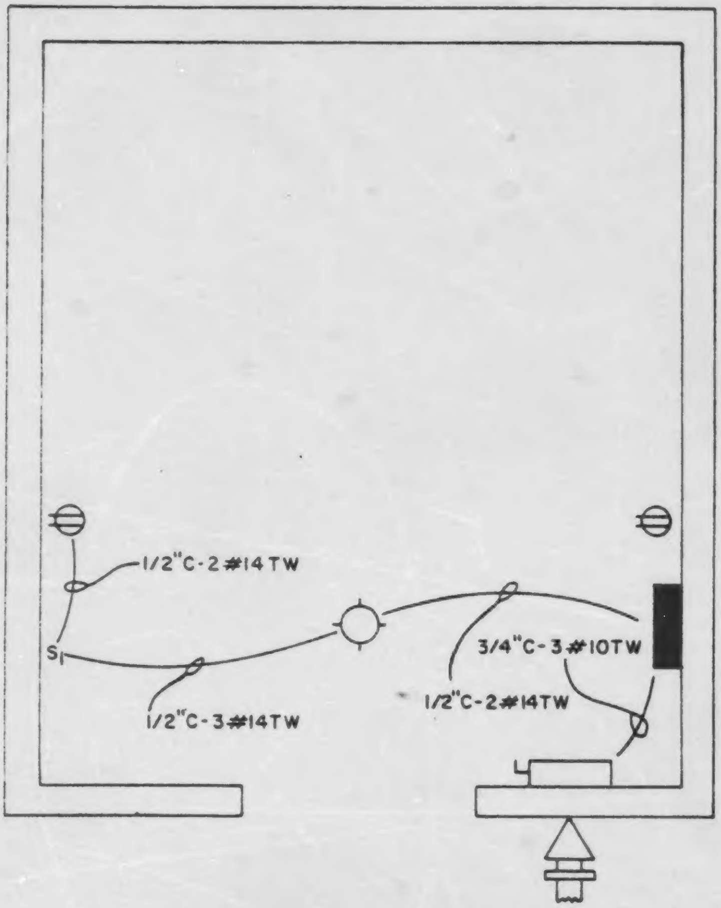
Use your single line drawing and connect the conductors. CAUTION: DO NOT APPLY POWER. Call the instructor ______________________ (Instructor)

Step nine

Operate the circuit when instructed to do so. The instructor will indicate if the circuit operates properly.

Step ten

Clean up the area and store tools and equipment.


1/2"C-2#14TW
S1
1/2"C-3#14TW
3/4"C-3#10TW
1/2"C-2#14TW

NOTES:

1. Lighting circuit to be run in 1/2" EMT.
2. Light switch to be 48" from floor.
3. Duplex outlet 12" from floor.

Figure 8

Project 9

Complete this project step by step. Call the instructor where indicated. Observe safety at all times.

Step one

Study the blueprint provided with this project, figure 9. Draw the equipment and supplies you will require from supply. Draw any equipment or supplies that are not available. Have instructor check drawings ______________________________
(Instructor)

Step two

Install the boxes as indicated on the blueprint. Check to see that they are level, properly secured to the structure, set to correct depth, and set to correct height.

Step three

Using 1/2" EMT, bend and cut the conduit to fit the runs.

Step four

Use conduit fittings and assemble the conduit runs to the boxes.

Step five

Secure the conduit to the structure.

Step six

Refer to your blueprint and make a single line drawing of the circuit to be installed. Use space below. Have your instructor check the drawing

____
(Instructor)

Step seven

Select the correct size and color conductors and pull the conductors into the conduit.

Step eight

Use your single line drawing and connect the conductors. CAUTION: DO NOT APPLY POWER. Call the instructor ______________________________
(Instructor)

Step nine

Operate the circuit when instructed to do so. The instructor will indicate if the circuit operates properly ______________________________
(Instructor)

Step ten

Police the area and properly store the tools and equipment.

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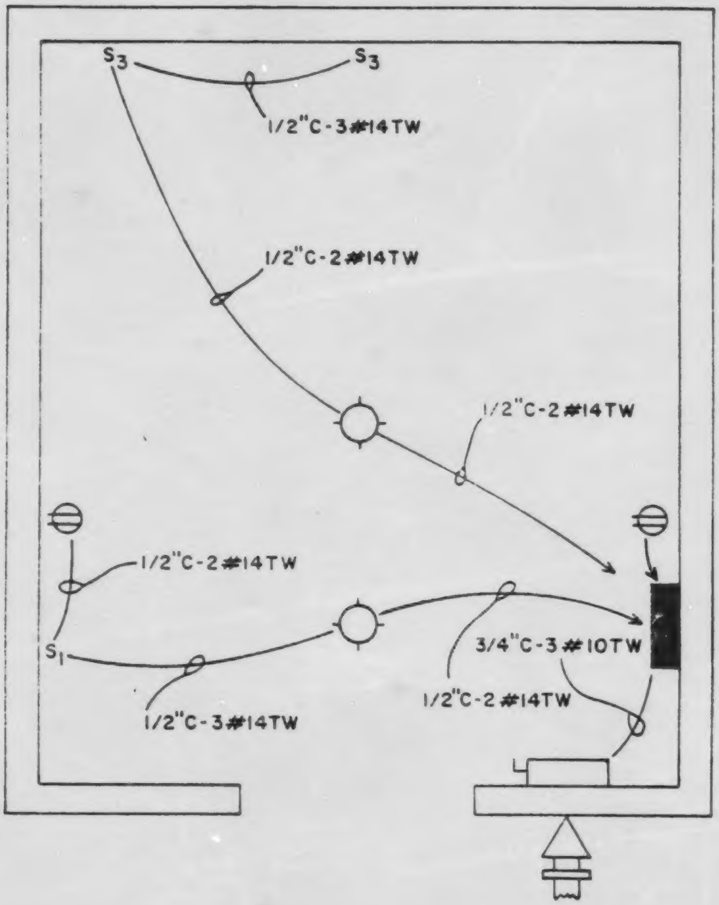

S3
S3
1/2"C-3#14TW
1/2"C-2#14TW
1/2"C-2#14TW
1/2"C-2#14TW
S1
1/2"C-3#14TW
3/4"C-3#10TW
1/2"C-2#14TW

NOTES:

1. Lighting circuit to be run in 1/2" EMT.
2. Light switches to be 48" from floor.

Figure 9

Project 10

Complete this project step by step. Call the instructor where indicated. Observe safety at all times.

Step one

Study the blueprint provided with this project, figure 10. Draw the equipment and supplies you will require from supply. List any equipment or supplies that are not available. Have instructor check list

____
(Instructor)

Step two

Install the box as indicated on the blueprint. Check to see that it is level, properly secured to structure, set to correct depth, and set at correct height.

Step three

Using 1/2" EMT cut the conduit to fit the run.

Step four

Use conduit fittings and assemble the conduit runs to the boxes.

Step five

Secure the conduit to the structure.

Step six

Refer to your blueprint and make a single-line drawing of the circuit to be installed.

Use space below. Have your instructor check the drawing ____________________
(Instructor)

Step seven

Select the correct size and color conductors and pull the conductors into the conduit.

Step eight

Use your single-line drawing and connect the conductors. CAUTION: DO NOT APPLY POWER. Call instructor ______________________________
(Instructor)

Step nine

Operate the circuit when instructed to do so. The instructor will indicate if the circuit operates properly ______________________________
(Instructor)

Step ten

Police the area and properly store the tools and equipment.

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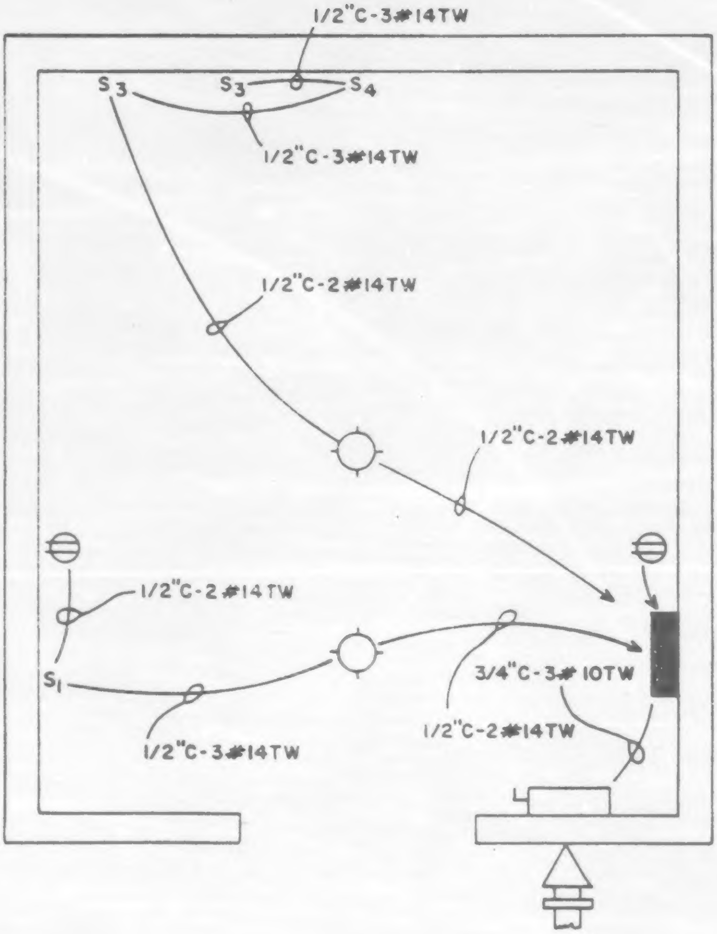

1/2"C-3#14TW
S3
S3
S4
1/2"C-3#14TW
1/2"C-2#14TW
1/2"C-2#14TW
1/2"C-2#14TW
S1
3/4"C-3# 10TW
1/2"C-2#14TW
1/2"C-3#14TW

NOTES:

1. Lighting circuit to be run in 1/2" EMT.
2. Light switches to be 48" from floor.

Figure 10

Project 11

Complete this project step by step. Observe safety at all times. Call the instructor as indicated in the project.

Step one

Study the blueprints provided with this project, figure 11. Make a list and draw all the required equipment and supplies from supply. Notify your instructor of any materials that are not available. Instructor will check list

______________________ (Instructor)

Step two

Install the disconnect as indicated on your blueprint. Check to see that it is level, at the correct height, and properly secured to the structure.

Step three

Use 3/4" EMT, bend and cut the conduit to fit the run. (You may refer to previous work projects.)

Step four

Use conduit fitting and assemble conduit runs to the boxes.

Step five

Secure the conduit run to the structure.

Step six

Refer to the blueprint and make a single-line drawing of the circuit. Color code your drawing. Have instructor check your drawing ______________________ (Instructor)

Step seven

Select the correct size and color conductor, pull the conductor into the conduit.

Step eight

Use the single-line drawing you have prepared and connect the conductors.

CAUTION: DO NOT APPLY POWER. Call the instructor ______________________ (Instructor)

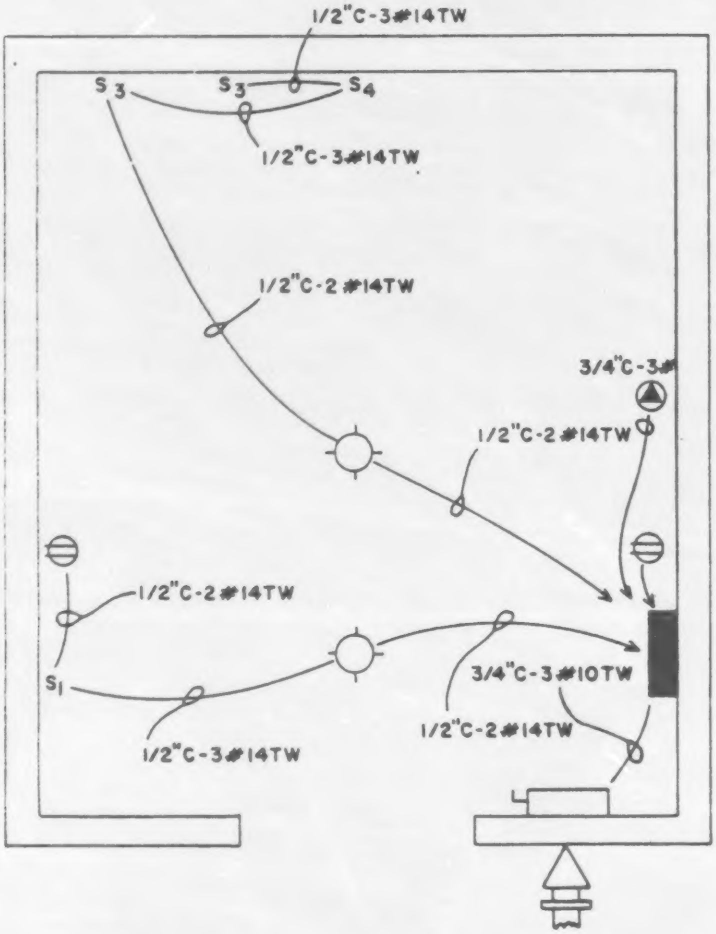
Step nine

Operate the circuit when instructed. Instructor will indicate correct operation

______________________ (Instructor)

Step ten

Clean up the area. Store tools and equipment.


1/2"C-3#14TW
S3
S3
S4
1/2"C-3#14TW
1/2"C-2#14TW
3/4"C-3#
1/2"C-2#14TW
1/2"C-2#14TW
S1
3/4"C-3#10TW
1/2"C-2#14TW
1/2"C-3#14TW

NOTES:

1. Disconnect is to be surface mounted on existing plywood.
2. Disconnect circuit is to be run in 3/4" EMT.

Figure 11

Project 12

Complete this project step by step. Observe safety at all times. Call the instructor as indicated in the project.

Step one

Study the blueprints provided with this project, figure 12. Make a list and draw all the required equipment and supplies from supply. Notify your instructor of any materials that are not available. Instructor will check list

____
(Instructor)

Step two

Install the box as indicated on your blueprint. Check to see that it is level, at the correct height, and properly secured to the structure.

Step three

Use 3/4" EMT, bend and cut the conduit to fit the run. (You may refer to previous work projects.)

Step four

Use conduit fitting and assemble conduit runs to the boxes.

Step five

Secure the conduit run to the structure.

Step six

Refer to the blueprint and make a single-line drawing of the circuit. Color code your drawing. Have instructor check your drawing

____
(Instructor)

Step seven

Select the correct size and color conductor, pull the conductor into the conduit.

Step eight

Use the single-line drawing you have prepared and connect the conductors.

CAUTION: DO NOT APPLY POWER. Call the instructor ______________________
(Instructor)

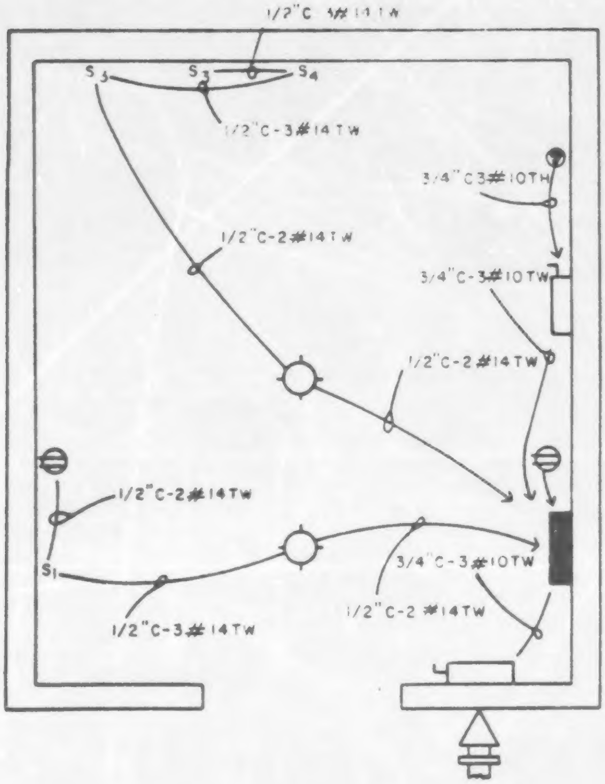
Step nine

Operate the circuit when instructed. Instructor will indicate correct operation

____
(Instructor)

Step ten

Clean up the area. Store tools and equipment.


1/2"C 3# 14 TW
S_3
S_3
S_4
1/2"C-3# 14 TW
3/4"C3# 10TH
1/2"C-2# 14 TW
3/4"C-3# 10TW
1/2"C-2# 14 TW
1/2"C-2# 14TW
S_1
3/4"C-3# 10TW
1/2"C-2 # 14TW
1/2"C-3# 14TW

NOTES:

1. Range outlet is to be surface mounted on existing plywood in a 4" square box.
2. Range circuit is to be run in 3/4" EMT.

Figure 12

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-5
August 1975

CIRCUIT EXTENSIONS

OBJECTIVES

1. Answer problems related to circuit extensions.
2. Install a circuit in surface metal raceway.
3. Balance branch circuits.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-III-5	1/student
Wiring Booth	1/student
Handtools	1/student
Materials	1/student

PROCEDURES

Project 1

1. Use your NEC to answer the following problems.
2. Article 352 of the NEC is labeled ______________ ______________.
3. Could surface metal raceway be used in wet areas? ______________________.
4. Who determines the number and size conductors in SMR? ________________.
5. Is it permissible to run SMR through a wall? ________________________.
6. Screws inside of SMR require what type heads? ______________________.
7. Should SMR be installed in:
   a. Dry locations? ________________
   b. Hoistways? ________________
   c. Hazardous locations? __________
   d. Office areas? ________________

Project 2

Follow this project step by step. Have your instructor check where indicated.

Step one

You are to install a circuit extension in surface metal raceway. This circuit extension will carry 15 amps of current. The blueprint will indicate which circuit will be extended and what it will contain. Figure 13.

1. Make a single-line drawing of the circuit extension with the proper color code. Have your instructor check the drawing

   ____
   (Instructor)

2. Make a list of the materials that you will need to install this circuit. Have your instructor check your list

   ____
   (Instructor)

Step two

1. Install the blank extension adapter over the existing outlet.
2. Mark and align the bases required for the circuit.
3. Fasten the bases in place with flat head wood screws of the correct size.

Step three

Measure and cut the surface metal raceway to length. Install the raceway.

Step four

Select the correct size and color conductor, then cut and pull in the conductor.

Step five

Refer to your single-line drawing and make your electrical connections.

CAUTION: DO NOT APPLY POWER. Have your instructor check your installation

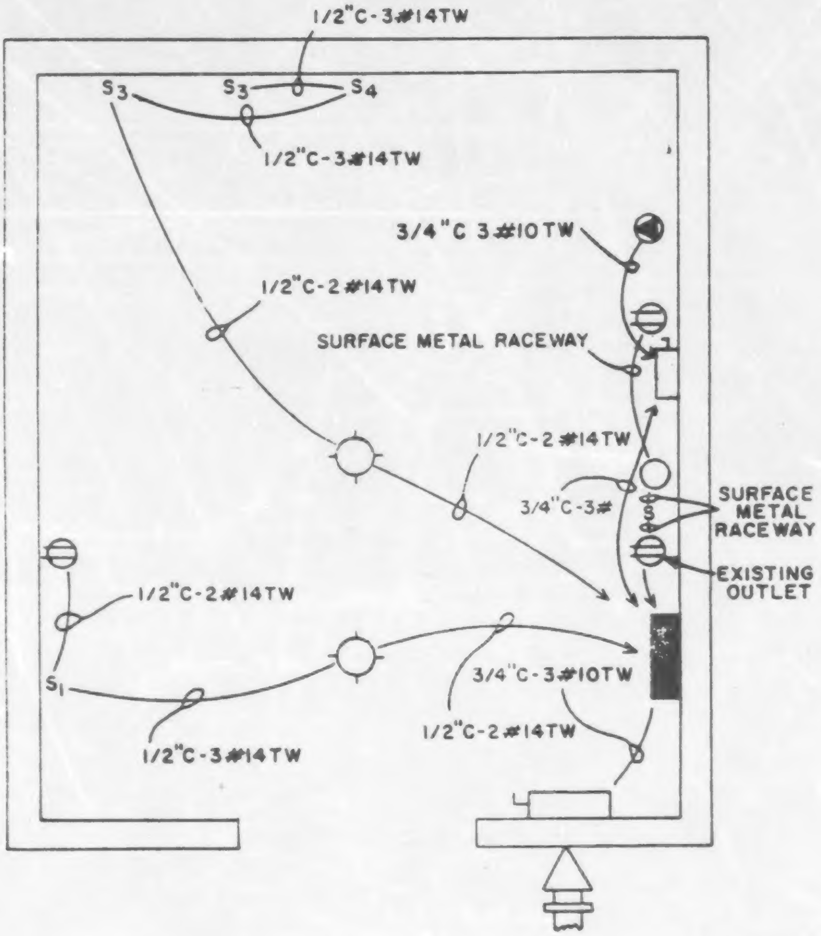
____
(Instructor)

Step six

Operate the circuit on instructions. Have instructor check ____________________
(Instructor)

Step seven

Clean up the area and store tools.


1/2"C-3#14TW
S3
S3
S4
1/2"C-3#14TW
3/4"C 3#10TW
1/2"C-2#14TW
SURFACE METAL RACEWAY
1/2"C-2#14TW
3/4"C-3#
S
SURFACE METAL RACEWAY
EXISTING OUTLET
1/2"C-2#14TW
S1
3/4"C-3#10TW
1/2"C-2#14TW
1/2"C-3#14TW

NOTES:

1. Circuit will be run from existing flush-mounted outlet.
2. Circuit will be run in surface metal raceway.

Figure 13

Project 3

1. This project will help you balance your branch circuits.
2. Turn power on to your booth.
3. Turn on main disconnect.
4. Turn on all branch circuits.
5. Check out a clamp-on ammeter.
6. Check current draw on each incoming conductor and record below.

   NOTE: This check may be accomplished at the service drip loop.

   a. Line #1 amps ____________________.

   b. Line #2 amps ____________________.

   c. Neutral amps ____________________.
7. Is your branch circuits balanced? ____.
8. If answer to step 7 is NO. What is your solution? __________________________

   ____

   ____
9. Have your instructor check your work.

____
(Instructor)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-6
August 1975

LOW VOLTAGE CIRCUITS

OBJECTIVE

Install a low-voltage circuit.

EQUIPMENT AND SUPPLIES	Basis of Issue
WB3ABR54230-1-III-6	1/student
Wiring Booth	1/student
Conduit Tools	1/student
Handtools	1/student
Materials	1/student

PROCEDURE

Project 1

Complete this project step by step. Call the instructor where indicated. Observe safety at all times.

Step one

Study the blueprint provided with this project, figure 14. Draw the equipment and supplies you will require. List any equipment or supplies that are not available. Have instructor check your equipment

____
(Instructor)

Step two

Refer to the blueprint and make a single-line drawing of the circuit. Have instructor check your drawing

____
(Instructor)

Step three

Install an octagon box above the distribution panel in the attic for a transformer.

Step four

Use 1/2" EMT, bend and cut the conduit to run from the panel to octagon box.

Step five

Use conduit fittings and assemble conduit run to the box and secure.

Step six

Mount the buzzer above the door and pushbutton next to doorway.

Step seven

Connect 120 volts to primary side of the transformer and mount the transformer to the octagon box using a round cover with a 1/2" knockout.

Step eight

Using #18 AWG bell wire, complete the connections for the low voltage circuit.

CAUTION: DO NOT APPLY POWER: Call the instructor.

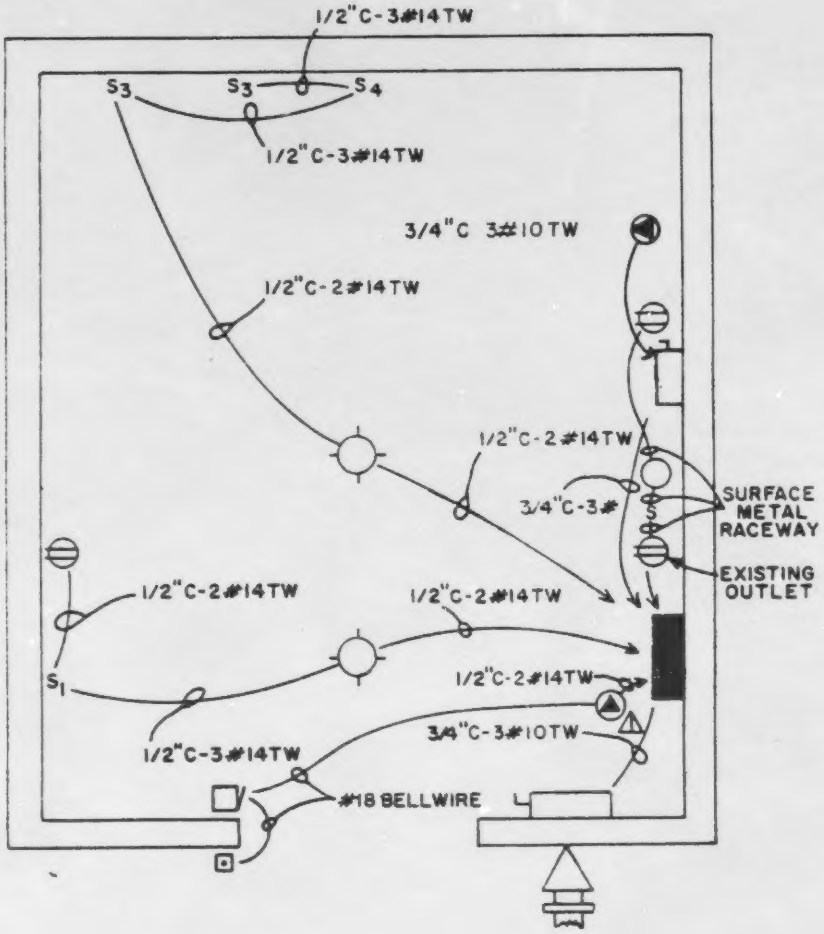
Step nine

Operate the circuit when instructed. Instructor will check for proper operation

____
(Instructor)

Step ten

Clean area and store tools and equipment.


1/2"C-3#14TW
S3
S3
S4
1/2"C-3#14TW
3/4"C 3#10TW
1/2"C-2#14TW
1/2"C-2#14TW
3/4"C-3#
SURFACE METAL RACEWAY
S
EXISTING OUTLET
1/2"C-2#14TW
1/2"C-2#14TW
S1
1/2"C-2#14TW
3/4"C-3#10TW
1/2"C-3#14TW
#18 BELLWIRE

NOTES:

1. Special Purpose $\triangle_2$ - 120/12V Stepdown Transformer Mounted on an Octagon Box Cover.

Figure 14

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-7
August 1975

TROUBLESHOOTING CONDUIT CIRCUITS

OBJECTIVES

1. Locate electrical troubles on an energized circuit.
2. Locate electrical troubles on a deenergized circuit.
3. Disconnect, sort materials, and store materials.

EQUIPMENT AND SUPPLIES	Basis of Issue
WB 3ABR54230-1-III-7	1/student
Handtools	1/student
Wiring Booth	1/student
Multimeter	1/student
Materials	8/students

Project 1

Follow this project step by step. You are to use the booth you have just wired. Your instructor will insert troubles in your booth.

Step one

You are to operate each circuit in your booth and for each one list the trouble you think exists in the circuit.

Circuit 1 ______________________

Circuit 2 ______________________

Circuit 3 ______________________

Circuit 4 ______________________

Circuit 5 ______________________

Step two

Select equipment needed to locate the troubles.

Step three

Use the following steps on each circuit you troubleshoot.

Step four

Use the schematic drawing that you prepared when installing this circuit. Study this drawing.

Step five

Make a visual inspection.

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Step six

Using proper equipment locate and indicate the exact location of troubles.

Circuit 1 ______________________

Circuit 2 ______________________

Circuit 3 ______________________

Circuit 4 ______________________

Circuit 5 ______________________

Have your instructor check ______________________ (Instructor)

Step seven

Repair troubles, have instructor check and operate ______________________ (Instructor)

Step eight

Remove all installed circuits, sort all materials and store in designated areas, have instructor check your area

______________________ (Instructor)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-III-8
August 1975

APPLIANCE MAINTENANCE

OBJECTIVE

List the correct solution to problems on appliance maintenance.

EQUIPMENT AND SUPPLIES

WB 3ABR54230-1-III-8

PROCEDURES

1. If an appliance is portable and will be moved from one area to another, what type of electrical connection is required?

____

2. List the three methods of repairing a broken heating element?

   a. ____________________

   b. ____________________

   c. ____________________

3. What meter is used to check a heating element for a break? ____________

4. Would a damaged bimetal strip be repaired or replaced? ____________

5. The first inspection to be done to a damaged appliance is a ____________ ____________.

DEPARTMENT OF CIVIL ENGINEERING TRAINING

ELECTRICIAN

BLOCK IV

MOTORS AND CONTROLS

JULY 1975

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

ELECTRICIAN

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3	Single-Phase Motor Systems	49
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This supersedes SG 3ABR54230-1-IV-1 thru 5, April 1973
(Superseded copies may be used until stock is exhausted.)

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-IV-1
July 1975

THREE-PHASE MOTOR SYSTEMS

OBJECTIVE

To enable you to understand the fundamentals, connections, and selection of three-phase motor systems.

INTRODUCTION

An electric motor converts electrical energy to mechanical energy. Motors fall into three basic types: AC, DC, and Universal. As an electrician you will need to understand the operating principles and know how to select and connect electric motors. You also need to know the various means of controlling an electric motor. This study guide was developed to aid you in understanding three-phase motors and their control systems.

INFORMATION

SECTION 1
FUNDAMENTALS

Three-phase motors are simple in construction and relatively low in initial cost. The most common types of 30 motors are the squirrel-cage induction motors and the wound rotor induction motor. These two types of motors vary only in the construction of the rotor. Three-phase motors are also referred to as polyphase motors. Three-phase motors can be broken down into three basic parts: (1) stator, (2) rotor, and (3) endbells.

Stator

The frame is made of cast iron or cast steel into which is pressed a laminated silicon steel core. The steel core is laminated to reduce "Eddy Currents," which is a loss due to stray currents. This steel core is constructed with semiclosed slots which hold the field windings. The field windings are made up of a number of varnished insulated coils, which are 120° (electrical) apart. These coils are insulated from the core with treated paper called fish paper. The coils are connected to form three separate windings. These windings are connected in either a wye or delta arrangement which will be explained later in this study guide. The field windings and the steel core together make up the stator or stationary part of the motor. Figure 1 shows the parts of a stator.

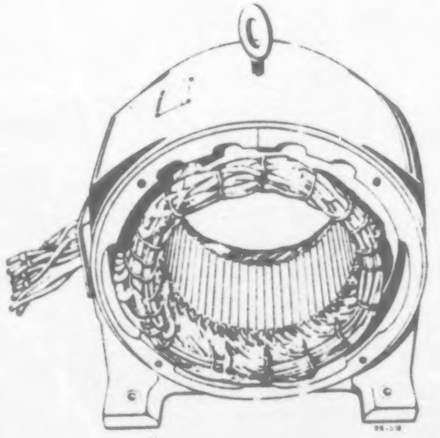


Figure 1. Three-Phase Stator

The kind of rotor used inside of the three-phase stator determines the type of motor. There are two types of rotors, the squirrel-cage rotor and the wound rotor.

Squirrel-Cage Rotor

The squirrel-cage rotor consists of a laminated silicon steel core, rotor bars, and end rings, mounted on a shaft. In the most recent types, the rotor bars are cast into place on an angle called skew. The skew effect increases the torque of the motor. The end rings short circuit or connect the rotor bars together. When one rotor bar is energized all of them are energized. The rotor bars and end rings together make up a squirrel-cage winding. Fan blades are added on the end of the rotor to assist in providing adequate ventilation for cooling. See figure 2.

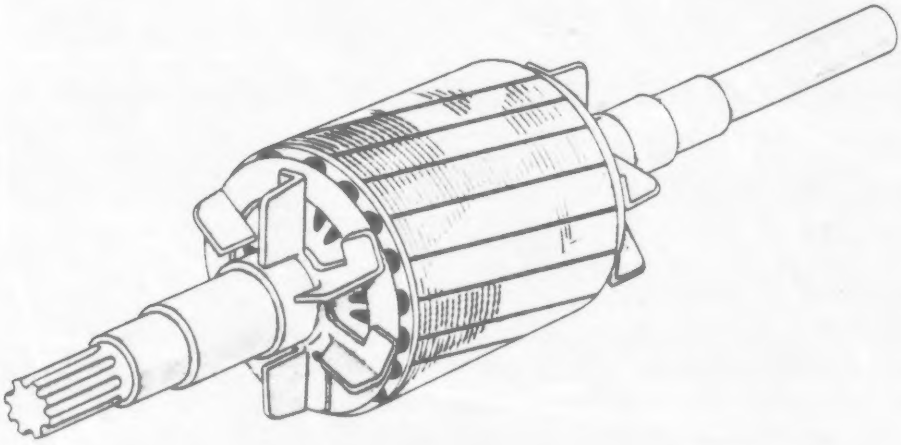


Figure 2. Squirrel-Cage Rotor

Wound Rotors

The wound rotor has a laminated silicon steel core mounted on a shaft. A rotor winding is wound around the core. The rotor windings are made of coils similar to those used in a stator. Each coil is made up of a number of turns of insulated copper wire. The windings are connected like those of the stator, wye, or delta. When the rotor is connected for wye operation one end of the windings are connected together in the center and the other end connected to sliprings mounted on the shaft. Brushes ride on the sliprings and are connected externally to resistors for variable

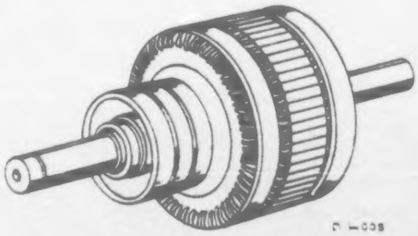


Figure 3. Three-Phase Wound Rotor

speed control. When connected for delta operation, the windings are internally connected into a delta configuration and three leads are connected to the sliprings. Wound rotor types of three-phase motors are used where a low starting current is desired with an external starting device. See figure 3.

Endbells

The endbells serve three functions: (1) house the bearings, (2) support and align the rotor and shaft, and (3) complete the frame of the motor.

Principles of Operation

The effects of a rotating magnetic field around the stator are required to cause a three-phase motor to operate. This magnetic field is caused by three factors:

(1) the difference in amount of current flow in the 3Ø power caused by the characteristics of 3Ø voltage generation, (2) reversal in direction of current flow caused by the characteristics of ac voltage, and (3) the arrangement of the field windings in the stator core to accomplish an even spread of magnetic field around the stator. The rotating magnetic field is set up by the rising and falling current in the stator windings. When the current reaches its maximum value in one winding, a strong magnetic field is produced by the winding. As the current in the first winding decreases, the current in the next winding increases, causing the magnetic field to move to that winding. As the current decreases in the second winding, it increases in the third winding, causing the magnetic field to move again. The windings are distributed so that this rotation of the magnetic field is uniform and continuous. See Figure 4.

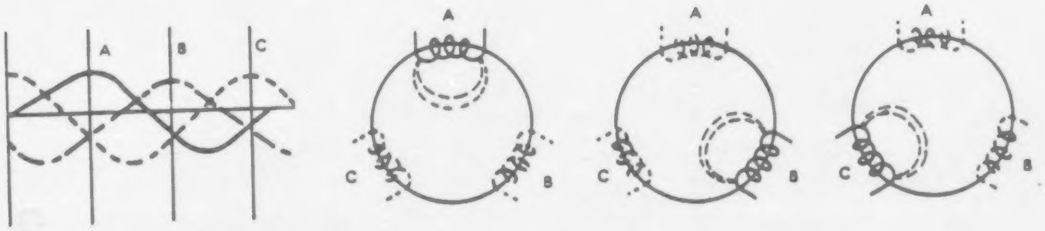


Figure 4. Rotating Magnetic Field

As the current flow builds up and collapses in the field windings, the magnetic lines of force cut across the rotor bars inducing a current flow. The current flow in the rotor sets up its own magnetic field, opposite to the stator field. The opposite magnetic fields attract and the rotor follows the rotating magnetic field. This will cause the rotor to turn at the same speed as the magnetic field, minus the slip.

Slip

The time lag between the speed of the rotating magnetic field (synchronous speed) and the rotor speed is called slip. Normal slip is 2 to 5% of synchronous speed. If slip increases, the torque (twisting effect of the shaft) increases. However 25 percent slip is called stall point and the rotor stalls or locks. This is normally caused if the motor is overloaded. To figure the percent of slip, synchronous speed must be figured. The formula for synchronous speed is:

Example: $\text{RPM} = \dfrac{\text{frequency X 120}}{\text{number of poles}}$

$$\text{RPM} = \frac{60 \text{ X } 120}{4}$$

$$\text{RPM} = \frac{7200}{4}$$

$$\text{RPM} = 1800$$

The synchronous speed for a four-pole motor is 1800 RPMs. A data plate located on the stator will give the motor speed (shaft speed) as 1725 RPMs. With these two figures slip can be determined as follows.

$$\% \text{ of slip} = \frac{\text{synchronous speed - rotor speed}}{\text{synchronous speed}} \text{ X } 100$$

$$\% \text{ of slip} = \frac{ss - rs}{ss} \text{ X } 100$$

$$\% \text{ of slip} = \frac{1800 - 1725}{1800} \text{ X } 100$$

$$\% \text{ of slip} = \frac{75}{1800} \text{ X } 100$$

$$\text{slip} = 4.1 \text{ percent}$$

Normally you can obtain the RPM of a motor from the data plate. However, in some cases, the data plate will be missing from the motor. If the motor is operational a tachometer can be used to determine the speed of the shaft.

Motor Connections

A three-phase motor has both internal and external connections. The internal connections determine whether the three sets of stator windings are connected delta or wye. The external connections are made with leads which are brought out to the terminal box of the motor. These leads provide a means of connecting the motor to a source of power.

Internal Connections

The two main types of internal connections used in three-phase motors are the wye and the delta.

The symbol for a wye connected motor is the symbol Y. Figure 5 is a schematic diagram of a wye connected motor for high voltage.

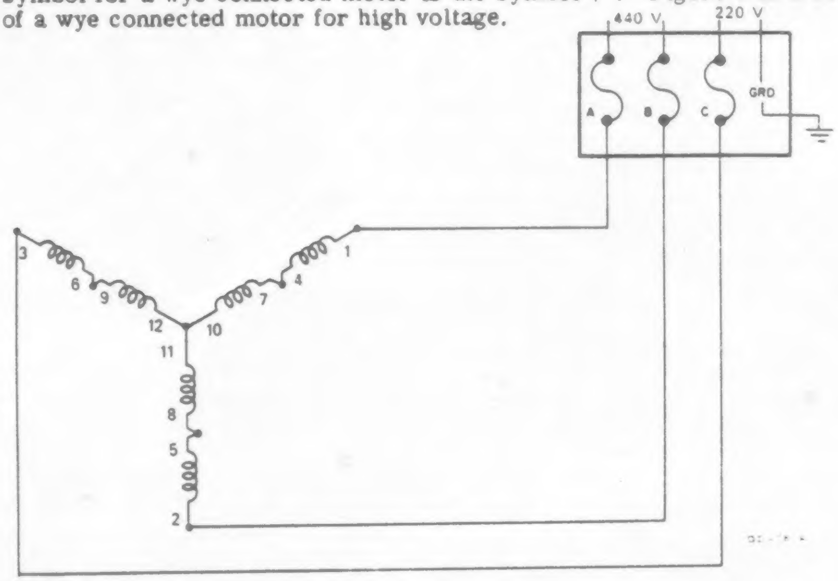

440 V
220 V
A
B
C
GRD
1
2
3
4
5
6
7
8
9
10
11
12

Figure 5. 440-Volt Circuit Diagram

NOTE: The schematic diagrams shown do not illustrate the true position of the coils in the stator.

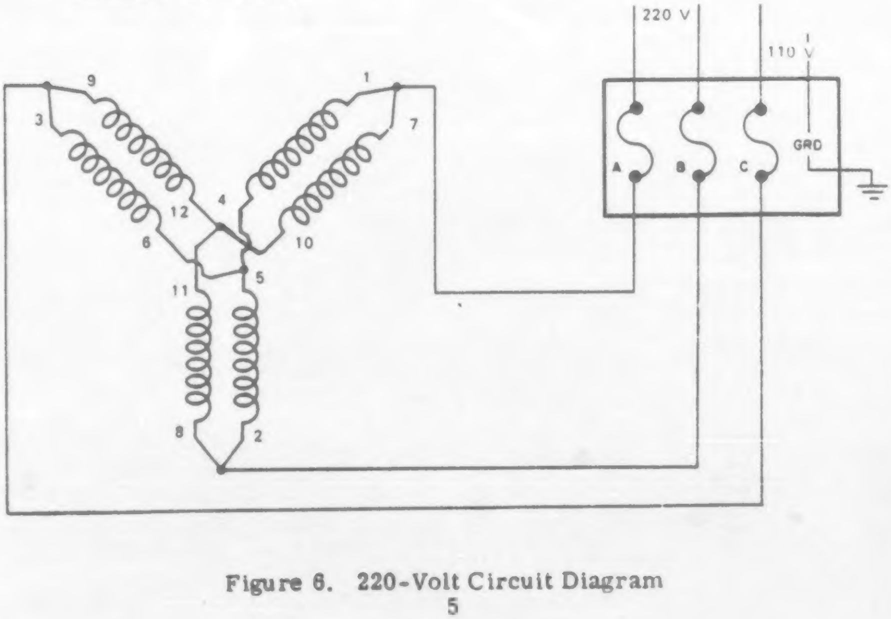

220 V
110 V
A
B
C
GRD
1
2
3
4
5
6
7
8
9
10
11
12

Figure 6. 220-Volt Circuit Diagram

Figure 6 shows a schematic diagram of a wye connected motor for low voltage.

The symbol for a delta connected motor is the Greek letter delta Δ .

Figure 7 shows a schematic diagram of delta connected motor for high voltage.

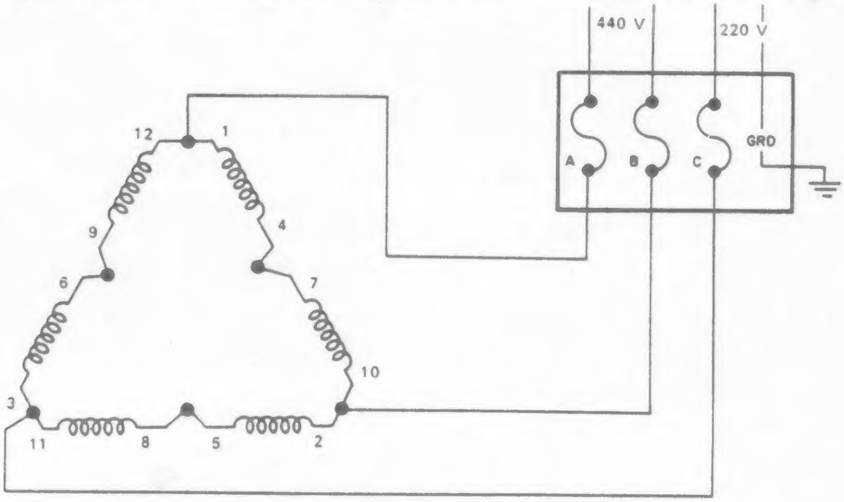

440 V
220 V
A
B
C
GRD
12
1
9
4
6
7
10
3
11
8
5
2

Figure 7. 440-Volt Circuit Diagram

Figure 8 shows a schematic diagram of a delta connected motor for low voltage.

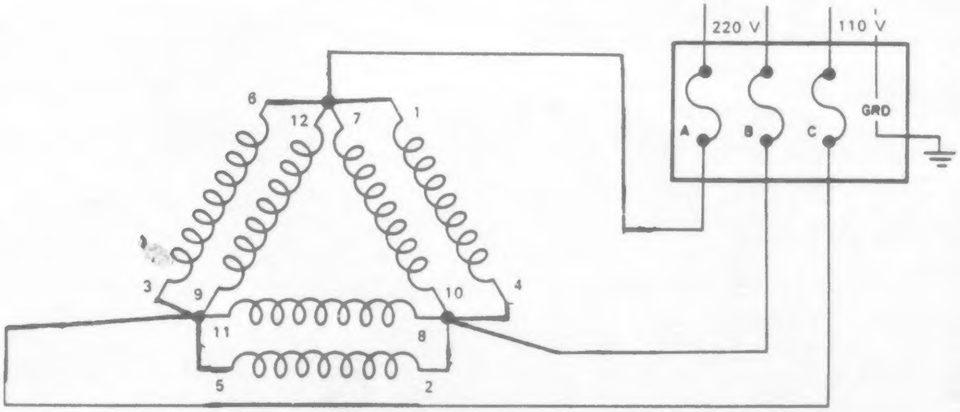

220 V
110 V
A
B
C
GRD
6
12
7
1
3
9
10
4
11
8
5
2

Figure 8. 220-Volt Circuit Diagram

To determine the direction of rotation of a three-phase motor, it is normally started before the load is connected. If the rotation is incorrect, you can change any two power leads to reverse the rotation of the motor. Figure 9 shows the schematic representation.

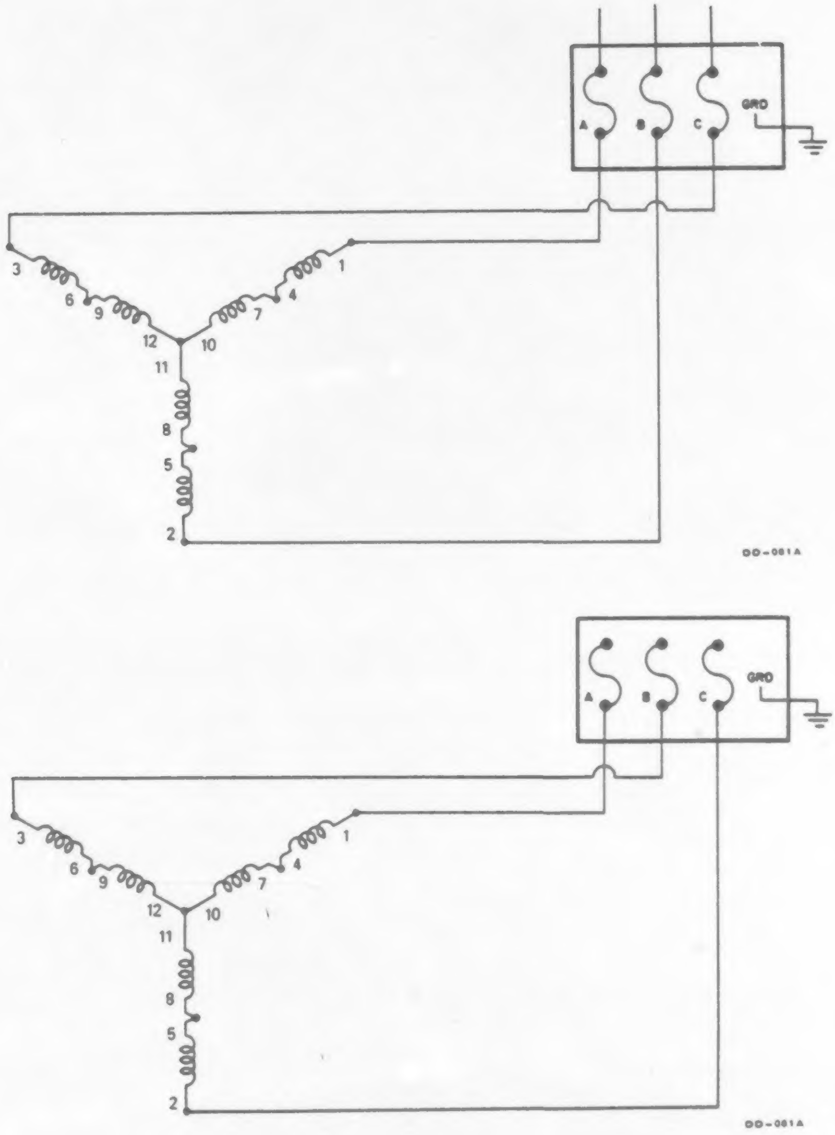

A
B
C
GRD
3
6
9
12
11
10
7
4
1
8
5
2
DD-081A
A
B
C
GRD
3
6
9
12
11
10
7
4
1
8
5
2
DD-081A

Figure 9. 440-Volt Circuit Diagram for Reversing Direction of Rotation

SUMMARY

The stator of a three-phase motor is constructed with semiclosed slots for windings which are connected either in a wye or in a delta fashion.

The kind of rotor used in a three-phase stator actually determines the kind of the three-phase motor. There are two distinct types of rotors: (1) the squirrel-cage and (2) the wound rotor. The squirrel-cage is the simplest in construction and requires less maintenance than the other types; therefore, it is the most popular. The three-phase motor operates on the theory of a rotating magnetic field established in the stator. Slip is the time difference between the rotating magnetic field and the rotor. Stall point is 25 percent slip and locks the rotor stationary. To figure amount of slip synchronous speed must be known. The formula for synchronous speed is $\text{RPM} = \frac{\text{frequency X 120}}{\text{number of poles}}$. With synchronous speed known, % of slip is figured with the following formula: $\text{Slip} = \frac{\text{ss - rs}}{\text{ss}}$ X 100 percent. The windings of three-phase motors are brought out from the stator to an external power source. The windings are connected for either wye or delta operation, 220-volt or 440-volt power supply. To reverse the direction of rotation of a three-phase motor, two power leads must be interchanged.

QUESTIONS

1. How can you reverse the direction of rotation of a three-phase motor?

2. What two things will change the speed of rotation of a polyphase motor?

3. What are the three main parts of a three-phase motor?

4. What is the principle of operation of a three-phase motor?

5. What are the two types of internal connections for a three-phase motor?

6. What are the four main parts of a squirrel-cage rotor?

7. Why are wound rotors used in three-phase motors?

8. How are the windings connected for high voltage (series or parallel)?

9. How many leads connect to the sliprings on a wound rotor?

10. Why are laminated cores used in motors?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electrical Motors
TO 34Y19-1-102, Maintenance of Electric Motors and Generators
Electric Motor Repair, Robert Rosenberg
Electric Motor Controls, Delmar Publishers

SECTION 2
THREE-PHASE MOTOR AND SYSTEM SELECTION

Motors chosen for a specific task must be properly rated, constructed, and protected for their work. Such factors as size, type of voltage, enclosure, speed, mounting requirements, direction of rotation, torque, types of bearings, shaft size, and temperature must be considered.

When selecting a motor for a specific function, one of the first things to consider is the available power. The power supply must have the required phases and voltage to run the size motor needed to drive the load.

Motors are classified according to size, as either being fractional horsepower or integral horsepower. A fractional horsepower motor is any motor rated less than one horsepower, while an integral horsepower motor is rated at one horsepower or larger. This classification is made by the National Electric Manufacturer's Association (NEMA).

Motors are also classed by construction or enclosure according to mechanical protection afforded or the method used for cooling.

Common types of enclosure are as follows:

* Open Motor - An open motor has ventilating openings in the frame which permit the passage of cooling outside air over and around the windings.

* Splashproof - A splashproof motor is an open motor in which the vent slots are made to prevent liquids or solids from entering them except at indirect angles.

* Totally Enclosed - This motor is built to prevent free passage of outside air. It is not airtight; therefore, it cannot be used in an explosive area.

* Drip Proof - A drip-proof motor is an open motor in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine, either directly or by striking and running along a horizontal surface, will not enter the motor.

* Waterproof Motor - A waterproof motor is a totally enclosed motor so constructed that it will exclude water applied in the form of a stream from a hose.

* Explosionproof - Explosionproof motors are designed to withstand an internal explosion of the vapors or dust from the area in which they are used and to prevent an explosion due to motor faults.

Location of installation will determine the type of enclosure of the motor. For example, an open motor would be used where the motor is protected from the elements by its surroundings. Totally enclosed motors would be used where there is a need to restrict the passage of outside air. Explosionproof motors are used where a hazardous condition exists or might exist. According to Article 500 of the N. E. C., hazardous locations are classed into three categories:

Class I - Locations containing flammable gasses or vapors.

Class II - Locations containing combustible dust.

Class III - Locations containing easily ignitable fibers or filings.

Article 500 of the N. E. C. also breaks down hazardous conditions into two divisions:

Division I - The hazardous condition is normally present.

Division II - The hazardous condition is not normally present but may occur.

Along with enclosures the location of the motor will also determine the temperature of the motor. Normal temperature rise of a motor is 40°C. This rise is added to the ambient (surrounding) temperature of the motor.

Duty of a motor is defined as the frequency in which it is started. This is an important factor in motor selection since motor windings heat rapidly during starting. For our purposes, we will divide motors into continuous duty and intermittent duty categories. Along with duty comes the term service factor. Since some motors are classed as general-purpose motors, they may have a service factor stamped on the data plate. The normal horsepower rating is multiplied by the service factor to give the safe overload capacity of the motor. For example, a five horsepower motor with a service factor of 1.15 can be used to carry a continuous load of 5.75 hp (5 X 1.15). Normal service factor is 1.15.

The types of bearings used in a motor usually depend on its application to a load or on its mounting plane, whether horizontal or vertical. As a general rule, sleeve bearing motors are horizontal mounted and ball or roller bearing motors are designed for vertical or horizontal mounting. The speed of the motor and size of the shaft are determined by the equipment to be driven or the load to be applied to the motor shaft. The connection to the shaft is made in different ways depending on the load. Keyway and key, pulley, couplings, and gears are common methods for connecting the shaft to the load.

According to the Article 430 in the N.E.C., motors shall be marked with certain information, such as the following:

1. Manufacturer's name.
2. Rated volts and full-load amps.
3. Rated frequency and number of phases.

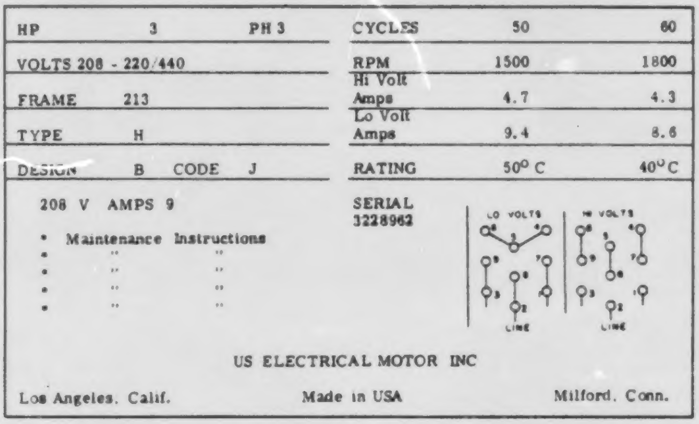
4. Rated full-load speed

5. Rated temperature rise

6. Time rating

7. Rated horsepower if 1/8 or more

Along with required information, manufacturers volunteer useful information, such as frame number, type, design, serial number, and motor connection. See figure 10.



HP	3	PH 3	CYCLES	50	60
VOLTS 208 - 220/440			RPM	1500	1800
FRAME	213		Hi Volt Amps	4.7	4.3
TYPE	H		Lo Volt Amps	9.4	8.6
DESIGN	B	CODE J	RATING	50° C	40° C

208 V AMPS 9

SERIAL
3228962

- Maintenance Instructions
- " "
- " "
- " "
- " "

US ELECTRICAL MOTOR INC

Los Angeles, Calif. Made in USA Milford, Conn.

LO VOLTS
HI VOLTS
LINE
LINE

DD-092

Figure 10. Motor Data Plate

Now that the motor has been selected for a specific job, the motor controller and related equipment must comply with the same requirements. If the motor enclosure must be explosionproof, then the controller when installed under the same conditions, must be explosionproof. The enclosure must be adequate for the location in which it is installed. The National Electric Manufacturer's Association (NEMA) has assigned enclosure numbers to identify the types of enclosures for controllers as follows:

Type 1 - open or general purpose

Type 3 - weather protected

Type 4 - moisture protected

Type 7 - hazardous vaporproof

Type 9 - hazardous dustproof

Type 7 & 9 - hazardous vapor and dustproof

Type 11 - oil emerged

Type 12 - oiltight, dust tight

Any additional information needed might be found in Article 430 of the N. E. C., entitled "Motors, Motor Circuits, and Controllers." To illustrate how this information would be used in selecting the correct motor and controller, let's look at a problem. A motor is needed to run an exhaust fan located in an aircraft hangar where hazardous gases and/or vapors are constantly present. The fan is rated as a 3 hp load. There is three-phase power available, 220 volts or 440 volts. The fan must be mounted in the ceiling thus the motor will be mounted vertically. The motor should be connected to draw the least amount of current possible. The motor will be a squirrel cage induction type. Using the N. E. C. Article 430, the following information can be found:

1. Table 430-150 of the N. E. C. shows the full load current of a 440-volt, 3-hp motor is 4. 8 amps.
2. Conductor size - Art. #430-22(a) (125% x 4. 8 amps = 6 amps) and table 310-16 (#14 AWG TW copper).
3. Conduit size - Table 3A, Chapter 9 (1/2" EMT)
4. Fuse Size - Art 430-52 and Table 430-152 (4. 8 amps X 300% = 14. 4 amps). Art. 240-6, 15 amp fuse.
5. Enclosure type - Art. 500-4 hazardous locations.
6. Bearing type -roller or ball

SUMMARY

To select the proper motor to do a job, many factors have to be considered. Among these are the type of power supply, amount of horsepower required, speed, and direction of rotation.

The environment the motor must operate in will determine the type of housing used to protect the motor, also the position a motor is mounted in will determine what type of bearings are needed.

The motor data plate furnishes much valuable information, such as hp, volt, amp, and service factor.

Controllers are selected to conform with the type of motor used for a certain job.

Motor installations may be broken down into three general types: (1) general purpose, (2) weatherproof, and (3) hazardous locations.

QUESTIONS

1. What two ways are motors classified according to horsepower?

2. How does a totally enclosed motor differ from an explosionproof motor?

3. What is meant by the term service factor?

4. What does the abbreviation NEMA represent?

5. Name the two classes of hazardous locations.

6. A Class II, Division I condition would be what type hazardous condition?

7. What article in N. E. C. pertains to motors?

8. Wire size and fuse size are dependent on what factor?

9. Will the motor data plate state the voltage rating of a motor?

10. What are the three most common bearings found in motors?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electrical Motors
TO 34Y19-1-102, Maintenance of Electric Motors and Generators
Electric Motor Repair, Robert Rosenberg
Electric Motor Controls, Delmar Publishers
National Electric Code

Equipment and Supplies	Unit/Issue
SW 3ABR54230-1-IV-1	1/student

SECTION 3
MOTOR CONTROLLERS AND CONTROLS

A motor controller is anything from a simple toggle switch to a complex system, which controls some operation of an electric motor.

At this point, you are to read Article 430 of the N. E. C. in its entirety. Article 430 allows certain motors under certain conditions to be controlled by a simple device, such as a toggle switch or safety switch, shown in figure 11.

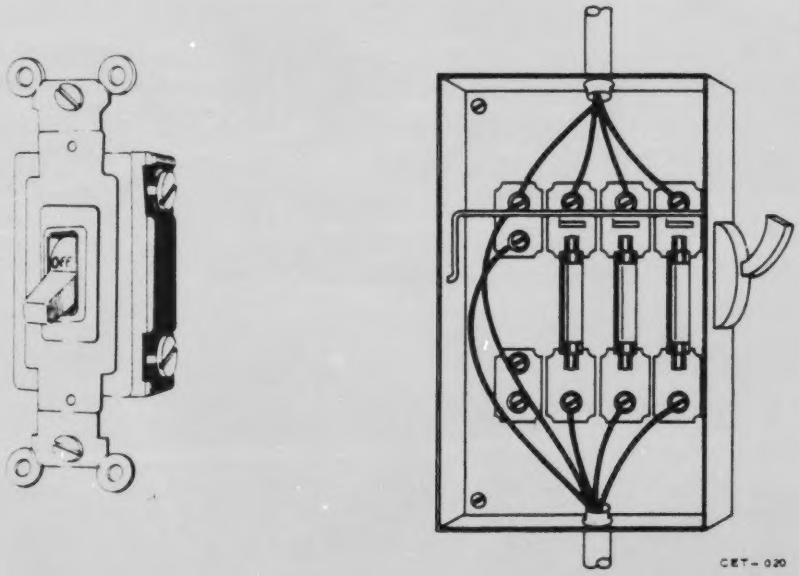


Figure 11. Toggle Switch and Safety Switch

Due to the size of a motor, the duty it is to perform, the location in which it is installed, or the construction of the motor, it may require additional protection and/or controlling devices.

Types of Manual Controllers

Toggle Switch - When a toggle switch is used to control a motor, it normally controls a motor of low horsepower rating. An example of this would be a bathroom exhaust fan.

Where the supply voltage to the motor is 240 volts, you would have to use a double-pole toggle switch. This would allow you to break both hot conductors simultaneously.

Safety Switch - Safety switches of all designs will also be used as controllers in some cases. A nonfusible safety switch would provide only a manual control means, where a fusible safety switch can in some cases provide overcurrent protection and control means. See figure 11.

A three-pole double-throw safety switch can be used to reverse the direction of rotation of a three-phase motor. See figure 12.

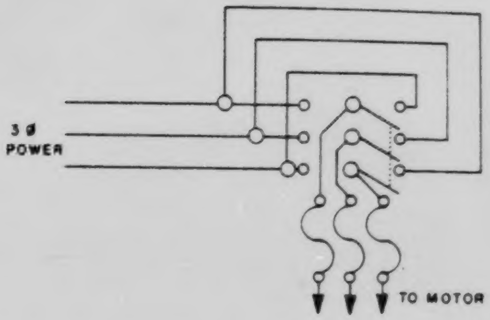


Figure 12. Manual Forward-Reverse Three-Phase Control

Drum Control - The drum control consists of a lever operated three-position switch encased as illustrated in figure 13. The center position is usually the OFF position with the right and left positions being forward and reverse respectively.

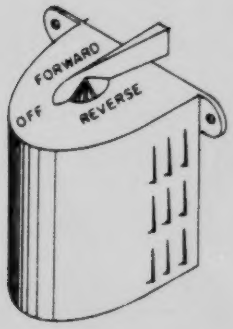


Figure 13. Drum Switch Control

An illustration of contact positions showing phase reversal at the forward and reverse positions is shown in figure 14.

The oil-immersed drum type is used extensively wherever the air may become charged with corrosive gases or highly flammable dust or lint. The drum type is frequently made for reversing service and for smaller multispeed squirrel-cage motors.

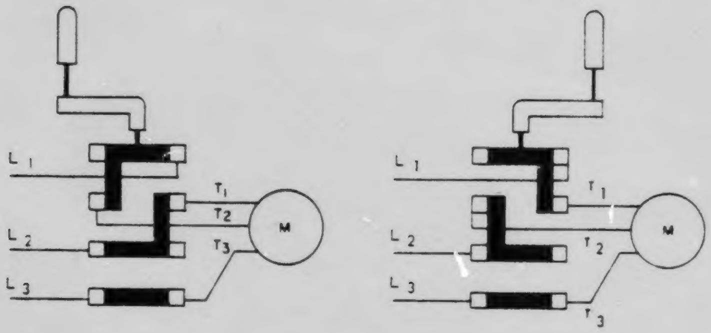


Figure 14. Reverse and Forward Drum Control Positions

Types of Automatic Controllers

Float Switches - The level of fluid is often controlled by the use of a float switch. This switch is a set of contacts which are opened or closed mechanically by a lever and float assembly. By using motor-driven pumps controlled by a float switch, the level of liquid can be increased or decreased automatically. An example of a common use of float switches is to control the water level in water towers.

Pressure Switch - Pressure switches are used to control the pressure of gases, air, and liquids within a desired range. For example a motor on an air compressor is controlled by a pressure switch.

Thermostat - The thermostat is a device sensitive to temperature and is widely used in heating and cooling systems to control the system.

Photoelectric Cells - The photoelectric cell is sensitive to light and is used widely to turn "on and off" exterior lights, such as street lights.

MAGNETIC LINE VOLTAGE STARTER

Electromagnetic energy can be used to close switches. Line voltage starters provide a safe, convenient, and economic means for controlling electric motors. They are used to start and stop electric motors. Magnetic line starters are widely used because they are economical and safe and they can also be controlled remotely. They are normally used where full voltage starting torque is needed and where current surge is not a major factor. Magnetic starters may be as simple as the type shown in figure 15, having only one set of contacts. The contacts called "main contacts" would be connected in series with the conductor carrying power to the motor. When the electromagnetic coil is energized, it sets up a magnetic field attracting the armature. When the armature moves toward the electromagnet, the movable contact (located on the armature) connects with the stationary contact. This completes the circuit to the motor and the motor starts. When the switch in the circuit which supplies power for the electromagnetic coil is opened, the coil is deenergized, causing a loss of the magnetic force. The spring will then pull the contacts apart. This is a simple magnetic line starter. Other magnetic line starters will have more contacts, motor overcurrent protector relays (heaters), and may depend on gravity to open the contacts. Heaters will be explained later in this study guide. Figure 16 will help you identify the different parts of a magnetic across the line starter. This figure shows a three-phase across the line starter, containing three sets of main contacts, one set of holding contacts, a coil, two reset contacts, and two heaters. It is designed so gravity will cause the contacts to open when the coil is deenergized. Pressure springs have been added to the contacts to allow them to seat evenly. This prevents bending of the contacts and arcing, thus prolonging their life. Shaded rings are placed on the stationary core to provide a time delay in the loss of flux, thus preventing contact chatter and wear in the moving parts of ac magnetic starters.

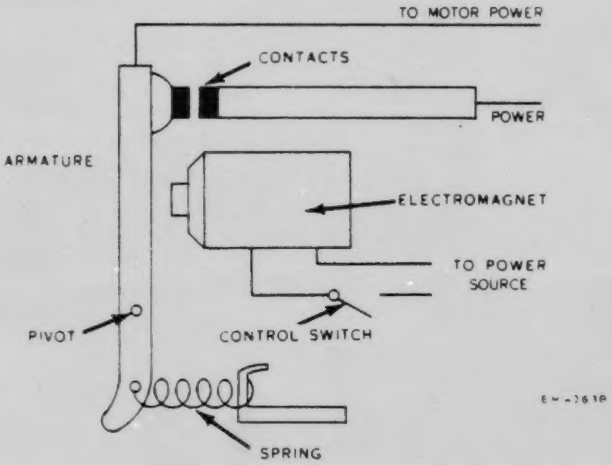


Figure 15. Magnetic Starter

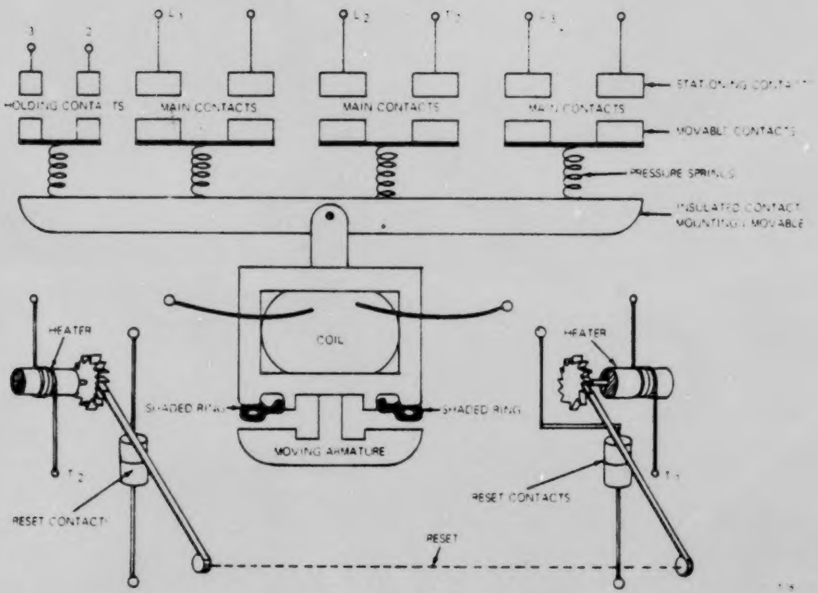

3
2
L1
L2
T2
L3
STATIONARY CONTACTS
HOLDING CONTACTS
MAIN CONTACTS
MAIN CONTACTS
MAIN CONTACTS
MOVABLE CONTACTS
PRESSURE SPRINGS
INSULATED CONTACT
MOUNTING - MOVABLE
HEATER
COIL
HEATER
SHADED RING
SHADED RING
MOVING ARMATURE
T2
T1
RESET CONTACTS
RESET CONTACTS
RESET

Figure 16. Three-Phase Magnetic Line Voltage Starter

Figure 17 shows how this starter will appear on an electrical diagram. Electrical symbols are used to represent the parts of the starter. Magnetic starters are often called contactors.

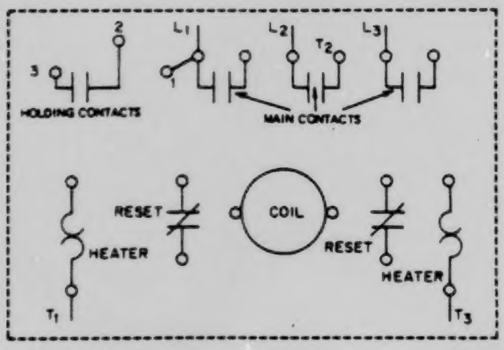


Figure 17. Electrical Diagram of a Magnetic Starter

Overload Protection

Electric motors require overload protection to prevent burnout. If permitted, electric motors will operate at a higher current than their rated capacity. This may be caused by low line voltage, by an open line in a three-phase system, and by an overload of the driven machinery. The overload on an electric motor causes it to draw excessive current that causes overheating. The overheating will eventually result in a burnout. To prevent this, overload relays are employed on a starter to limit the amount of current a motor can draw. This is overload protection, or running protection. An overload relay consists of a current sensitive element and a set of normally closed reset contacts. The overload relays of a starter function to protect a motor from excessive current that is destructive to motors. Current sensitive (thermal or magnetic) elements of overload relays are connected either directly or indirectly in the motor lines through current transformers. The overload relays act to deenergize the starter and stop the motor when excessive current is drawn.

Thermal Cutouts

Thermal cutouts are usually of the bimetallic or melting alloy types. The bimetallic type is constructed of two dissimilar metals which, when heated, bend due to the different rate of expansion of the two metals. A heating element in the motor line circuit generates the heat necessary to activate the strip. Current in excess of the desired amount causes deflection of the bimetallic strip to the extent that the contacts spring apart, thus opening the holding coil circuit as shown in figure 18. A reset button is depressed to reactiviate the mechanism when the strip has cooled to operating tolerance.

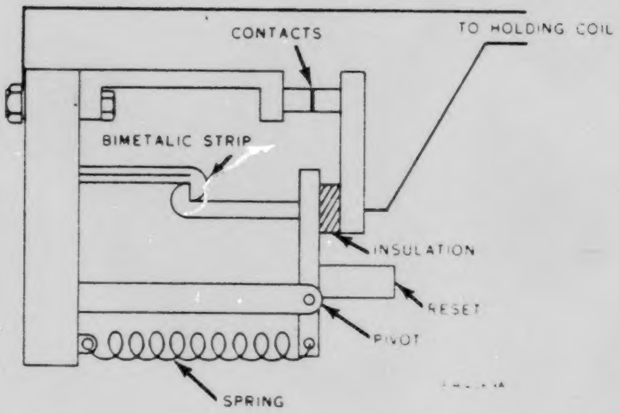

CONTACTS
TO HOLDING COIL
BIMETALIC STRIP
INSULATION
RESET
PIVOT
SPRING

Figure 18. Bimetallic Overload Relay

The melting alloy overload relay employs a heating coil connected in the motor line circuit. See figure 19.

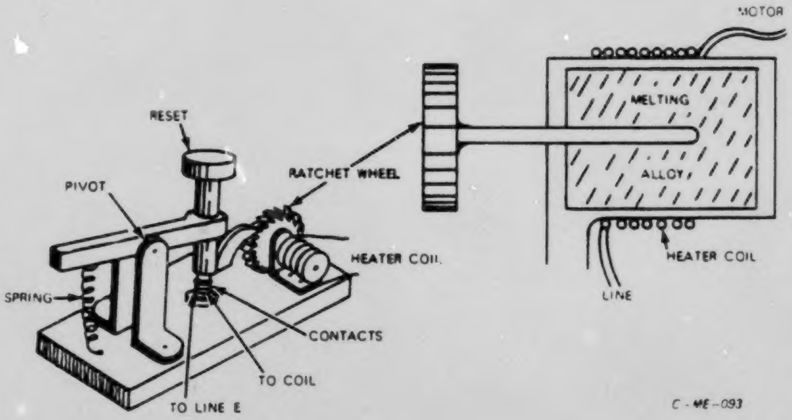

MOTOR
MELTING
ALLOY
RESET
RATCHET WHEEL
PIVOT
HEATER COIL
HEATER COIL
LINE
SPRING
CONTACTS
TO COIL
TO LINE E
C-ME-093

Figure 19. Melting Alloy Thermal Overload Relay

The heat caused by excessive current in the motor circuit melts the metal alloy (similar to solder) releasing the spring-loaded shaft. The shaft is then capable of turning which permits the reset contacts to open, thereby disrupting service to the motor. When the alloy has cooled and solidified sufficiently the motor may be restarted by depressing the reset button. A laboratory example of the melting alloy principle is shown in figure 19.

The main advantage of the melting alloy over the bimetallic type is its amperage rating doesn't vary after repeated heatings.

Magnetic Overloads

The magnetic overload relay consists of a coil, a plunger, a dashpot, and a set of contacts. See figure 20. The coil is connected in series with the motor. When a determined amount of current passes through the coil, the magnetic field will pull the plunger up causing the contacts to open. By adjusting the length of the plunger, the amount of current required to pull the plunger up can be varied. An oil-filled dashpot is added to provide a time delay. A plate on the bottom of the plunger is submerged in the oil and acts as a piston. The plate has holes in it that can be adjusted in size to change the time delay. When the coil pulls the plunger up, the oil must flow through the hole in the plate as the plunger rises. By changing the size of the hole, the time delay can be increased or decreased. Quick tripping is obtained through the use of a light grade dashpot oil.

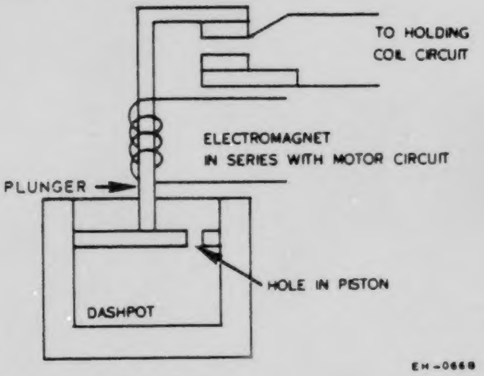


Figure 20. Magnetic Overload Relay

Selecting Heaters

The overload relay size is determined by the full load current of the motor it protects. When selecting the heaters to protect a motor, you should check the motor data plate to find the full load current. Each manufacturer normally puts a heater selection table in the controller cover. Heaters are not identified by amperage, but by the manufacturer's catalog number. By using the full load current of the motor to be protected and referring to the manufacturer's table, the proper heater can be selected. Figure 21 is a Cutler-Hammer heater table. If the full load current of a 2 hp motor at 230v is 6.8 amps, the heater required would be an H1033.

HEATER COIL SELECTION TABLES

For Size 1 Starter				For Size 2 Starter		For Size 3 Starter		For Size 4 Starter	
Ampere Range	Catalog No.	Ampere Range	Catalog No.	Ampere Range	Catalog No.	Ampere Range	Catalog No.	Ampere Range	Catalog No.
.157-.177	H1101	2.20-2.45	H1024	3.89-4.35	H1028	8.72-9.67	H1035	19.5-21.9	H1042
.178-.198	H1102	2.46-2.74	H1025	4.36-4.81	H1029	9.68-10.8	H1036	22.0-24.7	H1043
.199-.223	H1103	2.75-3.07	H1026	4.82-5.35	H1030	10.9-12.0	H1037	24.8-29.0	H1044
.224-.249	H1104	3.08-3.42	H1066	5.36-5.96	H1031	12.1-13.5	H1038	29.1-31.9	H1045
.250-.280	H1105	3.43-3.81	H1027	5.97-6.63	H1032	13.6-15.0	H1039	32.0-36.1	H1046
.281-.313	H1106	3.82-4.27	H1028	6.64-7.41	H1033	15.1-16.8	H1040	36.2-40.7	H1047
.314-.353	H1107	4.28-4.71	H1029	7.42-8.23	H1034	16.9-19.1	H1041	40.8-46.2	H1048
.354-.395	H1108	4.72-5.24	H1030	8.24-9.19	H1035	19.2-21.6	H1042	46.3-52.4	H1049
.396-.445	H1109	5.25-5.87	H1031	9.20-10.2	H1036	21.7-24.5	H1043	52.5-59.2	H1050
.446-.499	H1110	5.88-6.48	H1032	10.3-11.4	H1037	24.6-27.8	H1044	59.3-66.3	H1051
.500-.562	H1111	6.49-7.27	H1033	11.5-12.8	H1038	27.9-31.5	H1045	66.4-75.1	H1052
.563-.631	H1112	7.28-8.14	H1034	12.9-14.1	H1039	31.6-35.5	H1046	75.2-87.1	H1054
.632-.711	H1113	8.15-9.03	H1035	14.2-15.9	H1040	35.6-40.3	H1047	87.2-99.9	H1055
.712-.799	H1114	9.04-10.0	H1036	16.0-18.1	H1041	40.4-45.6	H1048	100.-113.	H1056
.800-.903	H1115	10.1-11.2	H1037	18.2-20.4	H1042	45.7-51.8	H1049	114.-129.	H1057
.904-1.01	H1116	11.3-12.5	H1038	20.5-23.3	H1043	51.9-58.6	H1050	130.-135.	H1058
1.02-1.13	H1117	12.6-13.8	H1039	23.4-26.5	H1044	58.7-65.2	H1051	-----	-----
1.14-1.27	H1018	13.9-15.6	H1040	26.6-30.3	H1045	65.3-74.3	H1052	-----	-----
1.28-1.43	H1019	15.7-17.7	H1041	30.4-34.7	H1046	74.4-86.3	H1054	-----	-----
1.44-1.60	H1020	17.8-19.9	H1042	34.8-39.6	H1047	86.4-90.0	H1055	-----	-----
1.61-1.79	H1021	20.0-22.5	H1043	39.7-45.0	H1048	-----	-----	-----	-----
1.80-1.98	H1022	22.6-25.3	H1044	-----	-----	-----	-----	-----	-----
1.99-2.19	H1023	25.4-27.0	H1045	-----	-----	-----	-----	-----	-----

Figure 21. Cutler-Hammer Heater Table

SUMMARY

By the use of the proper controller, it is possible to control and protect motors under any given situation. Magnetic live voltage starters are widely used because they can easily be controlled remotely.

QUESTIONS

1. What is a drum switch used for?
2. How many sets of main contacts does a three-phase magnetic starter have?
3. What is the purpose of the reset contacts in a magnetic starter?
4. Are the reset contacts in a magnetic starter normally open or normally closed?

5. What is the purpose of the magnetic coil in a magnetic starter?
6. What is the purpose of the shaded ring, located on the iron core of a magnetic starter?
7. How can the time delay be varied on the dashpot relay?
8. What are two types of thermal overload relays?
9. Heater size is determined by what characteristic of the motor?
10. List four automatic controls used to control motors?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electrical Motors

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Electric Motor Repair, Robert Rosenberg

Electric Motor Controls, Delmar Publishers

National Electrical Code

EQUIPMENT AND SUPPLIES	Unit/Issue
SW 3ABR54730-1-IV-1	1/student

SECTION 4
CONNECTING THREE-PHASE CONTROLLERS

Connecting three-phase controllers vary only in the location of the terminals and when the controllers are to serve different duties. Figure 22 shows a square D magnetic starter and a start-stop station controlling a three-phase motor.

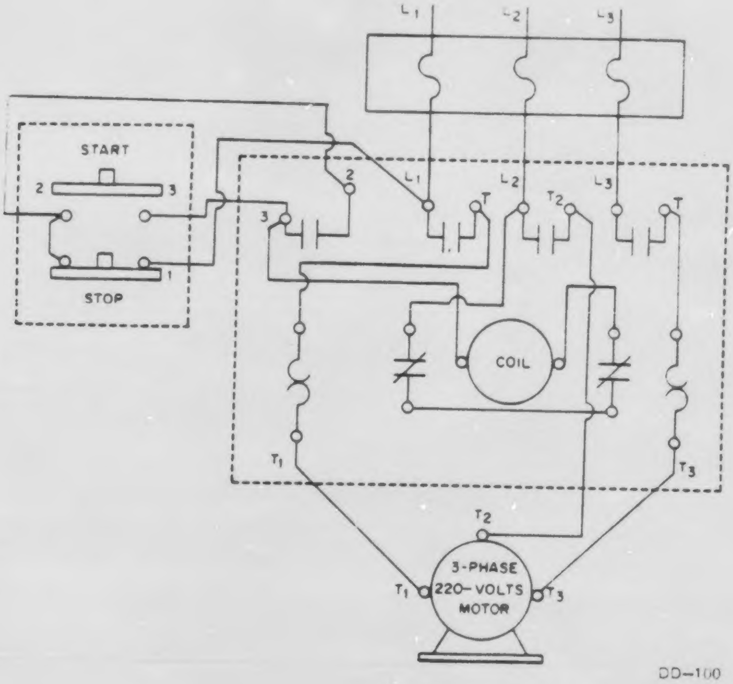


Figure 22. Wiring Diagram of a Square-D Magnetic Starter Connected to a Start-Stop Station

Power is supplied to the controller at terminals marked L1, L2, and L3. The motor is connected to three terminals marked T1, T2, and T3. The identification of these terminals will normally be the same regardless of the manufacturer.

In order for the motor to operate, three sets of normally open contacts (main contacts) must close. These contacts are located between the line and the load (L1 & T1, L2 & T2, and L3 & T3). To close these contacts the coil must be energized. This is done through a circuit known as the control circuit. The control circuit runs from terminal L2 through the two reset contacts (normally closed contacts) through the coil and to terminal three (3) on a set of holding contacts. To have a complete circuit to energize the coil, the control circuit must make connection to L1. This point is where the different types of controlling takes place. As in figure 22, terminal three (3) of the magnetic starter is connected to terminal three (3) of the start-stop station. When the start button is pushed, a circuit is completed from terminal three (3) through the start contacts to terminal two of the start-stop station, through the stop button to terminal one (1) and to terminal L1 of the magnetic starter. A circuit is now complete between L1 and L2, and the coil becomes energized. When the coil energizes, the armature is lifted causing all normally open contacts to close. The circuit is nowcomplete to the motor. The circuit from terminal three (3) of the magnetic starter to L1 is known as the start circuit. The start button on a start-stop station is a constant pressure switch, meaning it must be held in to keep the contacts closed. If pressure is removed, the circuit would be broken and the coil would become deenergized. To prevent this from happening, another circuit called a holding circuit is added. The holding circuit is connected from terminal two (2) of the magnetic starter to terminal two (2) of the start-stop station. When the coil becomes energized it closes all normally open contacts, including a set of holding contacts located between terminals two (2) and three (3) of the magnetic starter. When these contacts close, a circuit is completed from terminal three (3) through the holding contacts to terminal two (2), to terminal two (2) of the start-stop station, through the stop button contacts to terminal one (1) to L1. When the start button is released, this circuit is used to keep the coil energized. To deenergize the coil, pressure is applied to the stop button which causes its normally closed contacts to open, breaking the circuit, deenergizing the coil. Should the motor draw more current than is specified on the data plate, the overcurrent relays will heat and open the normally closed contacts (reset contacts) in the control circuit, which will deenergize the coil. This provides motor protection.

Figure 23 shows a wiring diagram of Arrow-Hart magnetic starter. As you can see, the terminals are marked the same as the Square D, but they are in different locations: even though the wiring remains the same. On some starters, terminals 2 & 3 may be marked C2 and C3.

When a motor system requires controlling from more than one location, additional start-stop stations can be added. Some conveyor belts require this type of control system to allow starting and stopping from either end of the conveyor.

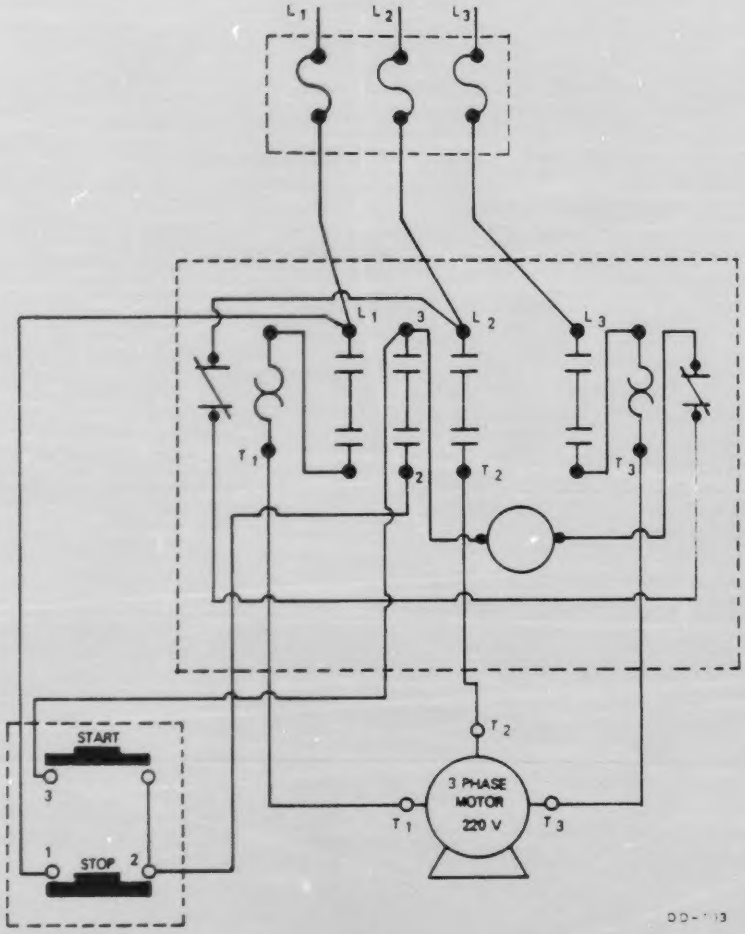
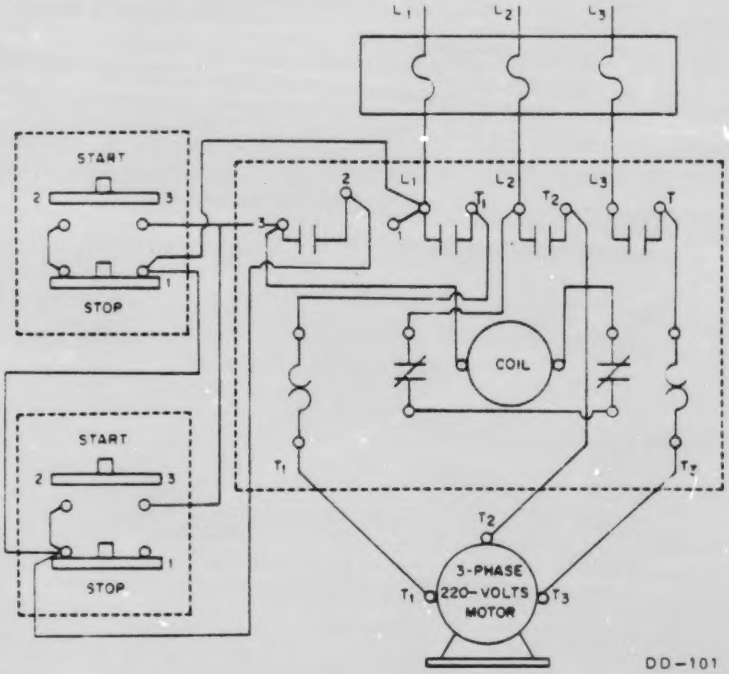

L1
L2
L3
L1
3
L2
L3
T1
2
T2
T3
T2
START
3
1
STOP
2
3 PHASE
MOTOR
220 V
T1
T3
DD-113

Figure 23. Wiring Diagram of a Arrow-Hart Magnetic Starter Connected to a Start-Stop Station

Figure 24 shows a diagram of how two start-stop stations are used to control a motor system. The two stop buttons are connected in series and the start buttons are connected in parallel.



L1
L2
L3
START
2
3
STOP
1
START
2
3
STOP
1
2
3
L1
T1
L2
T2
L3
T
COIL
T1
T3
T2
T1
T3
3-PHASE
220-VOLTS
MOTOR
DD-101

Figure 24. Wiring Diagram of a Magnetic Starter
Connected to Two Start-Stop Stations

When a thermostat, pressure switch, photocell, or any automatic control is used to control the magnetic starter, the holding circuit is not required. As shown in figure 25, the thermostat is connected to terminals L 1 and 3. The contacts in the thermostat provide a circuit to keep the coil energized; therefore, the holding contacts are not required.

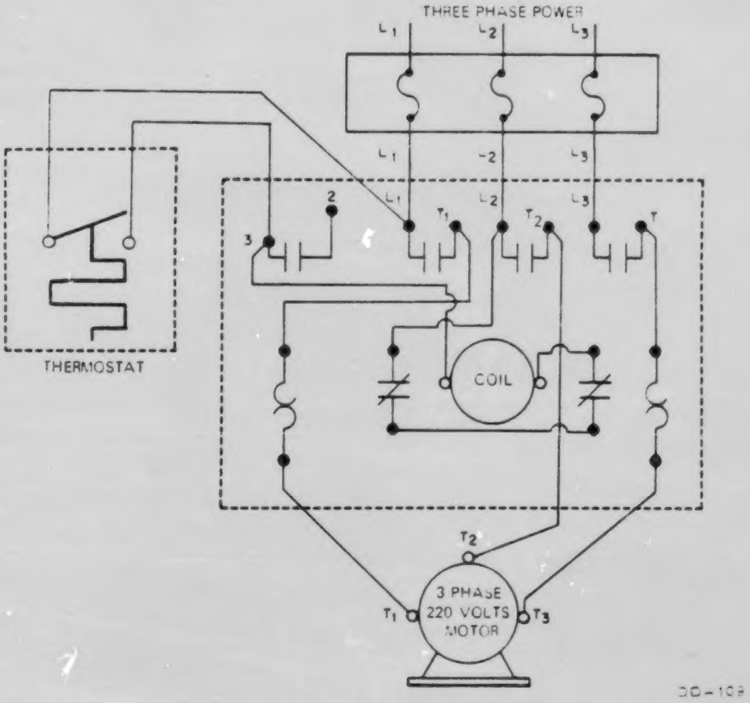


Figure 25. Thermostat Controlled Motor System

As you learned earlier, reversal in direction of rotation of a three-phase motor can be accomplished by changing two power leads. This can be accomplished with a drum switch. A more modern method used a "reversing starter." Reversing starters require two contactors, one for forward, the other for reverse. The contactors reverse line L1 and L3. Should both contactors close at the same time it would cause a short circuit. To prevent both contactors from closing at the same time, a mechanical interlock is used. To further prevent this the controls are so wired to provide an electrical interlock. Figure 26 shows a reverse controller. The forward and reverse station has a normally closed and a normally open set of contacts. If pressure is applied to the forward button it opens the normally closed contacts (which are in series with the reverse) and closes the normally open contacts, energizing the forward coil. The reverse button performs the same function in the reverse circuit. By opening the normally closed contacts an electrical interlock is provided.

Two sets of holding contacts are required in this controller, one in the forward circuit, the other in the reverse circuit, Label 2, 3 and 4, 5. Six sets of main contacts are required labeled L1, L2, and L3.

SUMMARY

The terminals on most magnetic starters are identified in the same manner. These terminals might vary in location from manufacturer to manufacturer. If you can connect

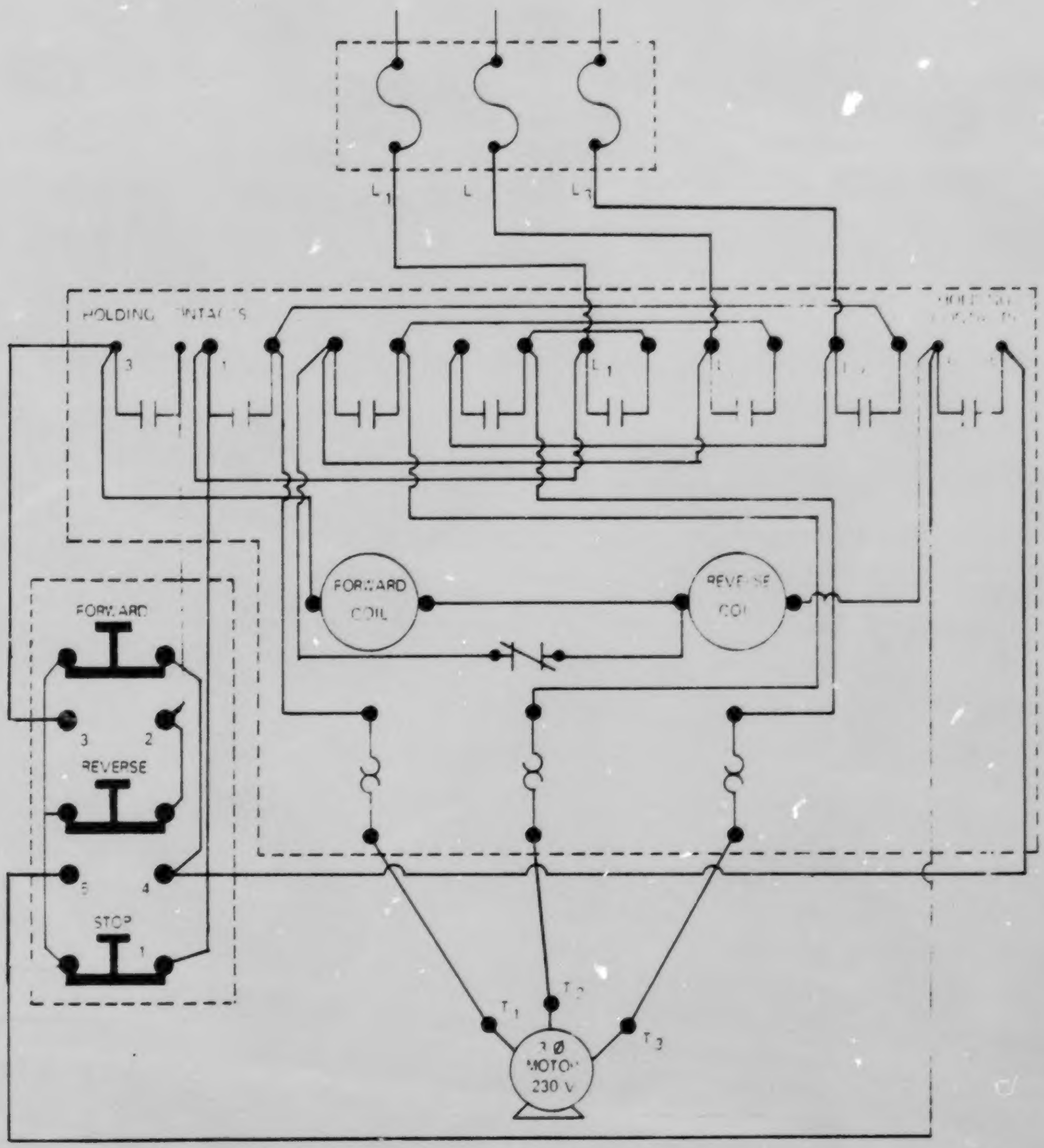

L1
L
L3
HOLDING CONTACTS
3
1
L1
FORWARD COIL
REVERSE COIL
FORWARD
3
2
REVERSE
5
4
STOP
1
T1
T2
T3
3 Ø MOTOR 230 V

Figure 26. Reversing Controller System

one type of magnetic starter, you can connect another type because the wiring connections are the same.

QUESTIONS

1. What is the purpose of the holding contacts?

2. The heaters are connected in what circuit of the magnetic starter?

3. The start contacts in a start-stop station are normally ______________ contacts. (Open or closed.)

4. The coil is connected in what circuit?

5. How is the electrical interlock provided in a forward-reverse control system?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electrical Motors

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Electric Motor Repair, Robert Rosenberg

Electric Motor Controls, Delmar Publishers

National Electrical Code

SECTION 5
REDUCED VOLTAGE STARTERS

Whenever the power system has insufficient capacity to allow full voltage starting of a motor, or whenever full voltage starting would cause line disturbances, reduced voltage starters are used. Reduced voltage starters are normally used on larger motors: however, they are sometimes recommended for motors as small as five horsepower.

Placing a resistance in series with the power leads reduces the voltage applied to the motor windings, which in turn reduces the current flow causing the motor to start slowly. As the motor picks up speed, a counter EMF is generated which keeps the line current at normal value. The starting torque is greatly reduced due to the reduced current flow. Two common types are the resistance starters and the autotransformers.

Resistor Type Motor Starters

The resistance starter employs resistors to reduce the input voltage, while the motor is starting. The resistance type starter consists of a heavy-duty resistance placed in series with the line conductors, as shown in figure 27.

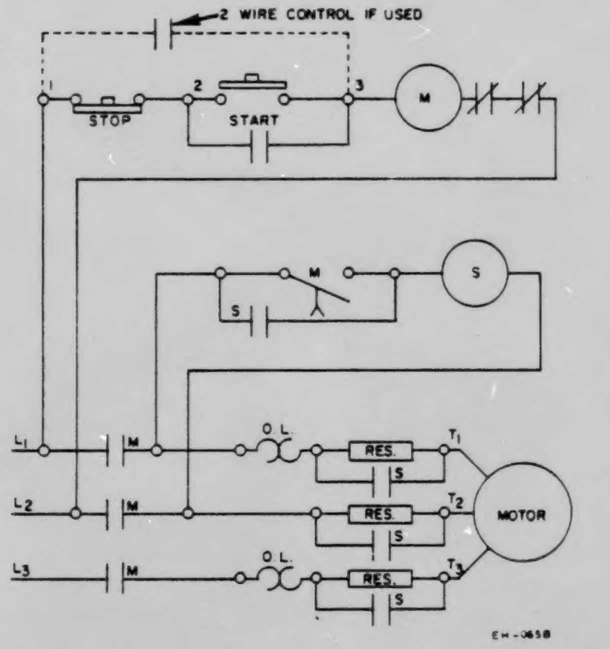


Figure 27. Diagram of a Primary Resistor Type Automatic Starter for Squirrel-Cage Induction Motors

The voltage drop through the line is due to resistors. The starting current of the motor is reduced in direct proportion of the voltage. The disadvantage of the resistor starter lies in wasted energy caused by the resistor heat loss.

Low voltage controls are devised for low voltage protection and low voltage release.

A low-voltage protection device is one which operates due to the reduction or failure of voltage, causing an interruption of power to the main circuit and maintaining the interruption of power to the main circuit.

A low voltage release device is one which operates due to the reduction or failure of voltage, causing an interruption of power to the main circuit, but reestablishing the main circuit on the return of voltage.

To obtain low-voltage protection it is necessary to have a start button that closes the control circuit only when it is being held down. A holding circuit keeps the control circuit closed after the start button is released. In the event of voltage failure the control circuit is opened and remains open. This gives protection against unsupervised starts when power returns.

NOTE: Overload device, in the control circuit, is in series with the coil.

A low-voltage protection device requiring personal intervention in order to restart the motor is considered a manual device.

A low-voltage release control operates automatically to restart the motor after the return of voltage. A different type of pushbutton station must be used with the low-voltage release control. The pushbutton must be a maintained contact type. This station does not use start contacts which are in the normally OPEN position. If the contactors should be opened due to a power interruption, the motor is still connected across a source of power, except for the opened overload switch in series with the coil. When voltage returns the motor will automatically restart. Automatic reset overload relays in magnetic starters connected by a two-wire switch will not protect the motor against sustained low voltage.

Autotransformers

Large motors require more intricate starters than those used for small motors. This is due to the heavy current draw of large motors while starting. The autotransformer starter is used to reduce the voltage and current to the motor.

The autotransformer, sometimes referred to as a compensator, is a coil or wire wound on a laminated iron core. Several taps are brought out to provide different voltages. On the common type compensator, three autotransformers, one for each phase of the line, are connected, as shown in figure 28. If each coil is tapped at the appropriate position and connected as shown in figure 28 to a three-phase motor, the voltage applied to the motor on starting will be one-half the line voltage. Due to the input voltage being reduced to one-half, the line current will also be reduced.

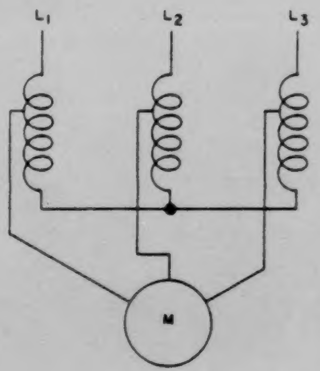


Figure 28. The Connection of a Start Position of a Compensator

The ordinary compensator usually has two or three taps brought out, so that different voltages are available, offering a choice of voltage to be applied to the motor on starting. The starter connection should be connected to the tap which offers the most satisfactory starting torque at the lowest start current.

The autotransformer starter is made in two types, the manual and automatic. The automatic and manually controlled compensators are essentially the same. The automatic compensator however, shown in figure 29, uses a start coil in the starting circuit and a run coil in the running circuit. The automatic starter is put in operation by pushing a remote control button which closes the start contacts magnetically. A timing device connects the motor across the line through the run contacts after it has been operating a few seconds on reduced voltage.

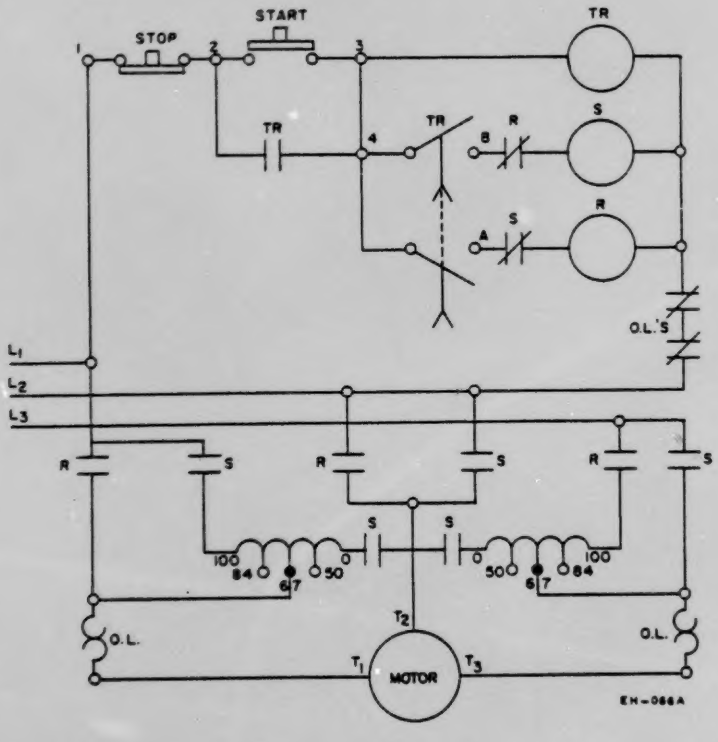


Figure 29. Automatic Autotransformer Controller Compensator

The manually operated type autotransformer starter has a handle which is used to manually place the motor in start and then run. Only one coil is required in the manually operated compensator. The manually operated compensator may or may not be connected through the overload relays while the motor is starting. If the overload relays are not in the starting circuit, no trouble will be encountered in the relay tripping because of an excessive starting current.

If the voltage fails, or is reduced, the holding coil is unable to hold the control in the run position. If a prolonged overload occurs, the overload relay contacts open and deenergize the holding coil. The holding, or undervoltage coil, is connected across two leads of the motor with a stop button and overload relay contacts in series with it. The overload relay must be reset before the motor can be started.

SUMMARY

Abnormally high starting currents in large three-phase motors are overcome by decreasing the voltage to the motor. By using resistors and autotransformers in series with the line reduces the voltage to the motor windings and lowers the starting current to a point where it will not be dangerous to the lines and equipment.

QUESTIONS

1. What is the purpose of a reduced voltage controller?
2. How are the resistors connected in the circuit in a resistor type starter?
3. What is the disadvantage of resistor type controller?
4. What is the purpose of the timing device used in an autotransformer controller?
5. Why does the autotransformer have more than one tap?

REFERENCES

TO 34Y19-1-1, Use Care, and Maintenance of Electrical Motors

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Electric Motor Repair, Robert Rosenberg

Electric Motor Controls, Delmar Publishers

National Electrical Code

Department of Civil Engineering Training
Sheppard Air Force Base, Texas 76311

SG 3ABR54230-1-IV-2
July 1975

TROUBLESHOOTING THREE-PHASE MOTOR SYSTEMS

OBJECTIVE

The objective of this study guide is to help you become familiar with the procedures for troubleshooting, testing, maintaining, and repairing motors and motor control systems.

INTRODUCTION

Motor failure may be due to a number of causes. Some of the things that may cause motor failures are an overload, low or high voltage, frozen or worn motor bearings, failure of motor windings, and failure of motor controls.

CONDITIONS THAT CAUSE MOTOR TROUBLE

Many things that cause motor failure are not the fault of the motor. Several conditions which may cause motor failure are listed below. These conditions should be checked before disconnecting electrical powerlines or troubleshooting the electrical system.

- Overload
- Loss of Power
- Driven Machine Blocked
- Frozen or Worn Bearings
- Bad or Improper Connections

Overload

If a three-phase motor has been operating satisfactorily and suddenly stops, a temporary overload condition may exist. Sufficient time should be allowed for the overload device to cool before actuating the reset device. If sufficient cooling has occurred the reset will hold in the locked position and the normal starting operation can be followed. If the motor fails to start, a systematic procedure should be employed for locating the trouble. Check current draw with an ammeter to determine if the motor is overloaded.

Loss of Power

Use a voltmeter to determine if power is being supplied to the magnetic starter. Likewise determine if power is being supplied to the motor.

Bad or Improper Connections

Before a motor is removed from the line all electrical connections should be checked. Determine if the control connections are in accordance with the control wiring diagram. When the control connections have been checked, the terminal lead connections in both the control apparatus and to the motor should be checked.

Motors with wound rotors are more susceptible to malfunctions due to their construction. Other than insulation checks which are similar to the stator winding, rotors often have opens caused by overheat. Conductors must be resoldered to the sliprings and rebanded if necessary.

Brushes that have been worn to half their original length must be replaced. Check brushes for broken leads, chipped or broken face, correct tension, and freedom of movement in holder.

Driven Machine Blocked

Determine if the driven machine is at fault. Disconnect the motor from its load and rotate the rotor shaft of the motor by hand to determine if rotation is free. By accomplishing this, it can be determined if the driven machine is at fault.

Frozen or Worn Bearings

Try operating the motor without the load of the driven machine. Lubrication may be needed and in some cases will free the rotor. If the bearings are frozen or stuck, it may be necessary to take the motor apart to free the bearings. If the rotor shaft will turn, look for wobbling, which indicates a bent shaft. Before handling the shaft however, put on gloves, or use a piece of cloth, to insure against injury to hands from burrs or sharp edges that may be in the keyway. Check the rotor shaft for any up and down play (movement). Any noticeable movement indicates worn bearings, which may be causing the rotor to be dragging in the stator. This is probable when belt tension is applied. The bearings should be replaced if up and down movement is noted. Also check for rotor end play. This is noted by moving rotor shaft in and out. Some end play is not detrimental; however, it should not exceed 1/64 of an inch. Excessive end play may be removed by adding fiber spacer washers.

Other things to check are: misalignment of endbells, a loose pole piece or foreign objects in the motor. If the trouble is not mechanical, the motor circuits are then analyzed.

PROCEDURES FOR TROUBLESHOOTING MOTOR SYSTEMS

All electrical circuits are subject to three common malfunctions. These circuit faults are: open, grounded, and shorted circuits.

Open Circuits

Starting with the source of power, an open circuit may exist at any point between there and the rotor of the motor. It is necessary to isolate the trouble. This must be accomplished on a step-to-step basis. Make the following checks on the equipment shown in figure 30.

Check with an ohmmeter from the source of power to the line terminals of the starter, making sure continuity exists at the starter line terminals, L1, L2, and L3. Make sure of a continuous circuit between the start-stop station and the starter. This calls for checking the starting circuit from the starter to the switch, if the motor will not start; and the holding circuit from the starter to the switch, if the motor does not operate after releasing the start button. NOTE: THE CONDUCTOR CONNECTED TO L1 IS COMMON TO BOTH THE STARTING AND HOLDING CIRCUIT. Make sure there is a continuous path for current flow from the switch side of the starter through the holding coil and through the resets, back to L2. This circuit normally is from switch terminal 3, to starter terminal L2. Be sure you have continuity through the heaters. Raise the armature until the contacts are closed and check for continuity between L1 and T1; L2 and T2; L3 and T3. If there are no opens to this point, power should exist to the motor terminals, T1, T2, and T3 of the starter, when the start button is pushed.

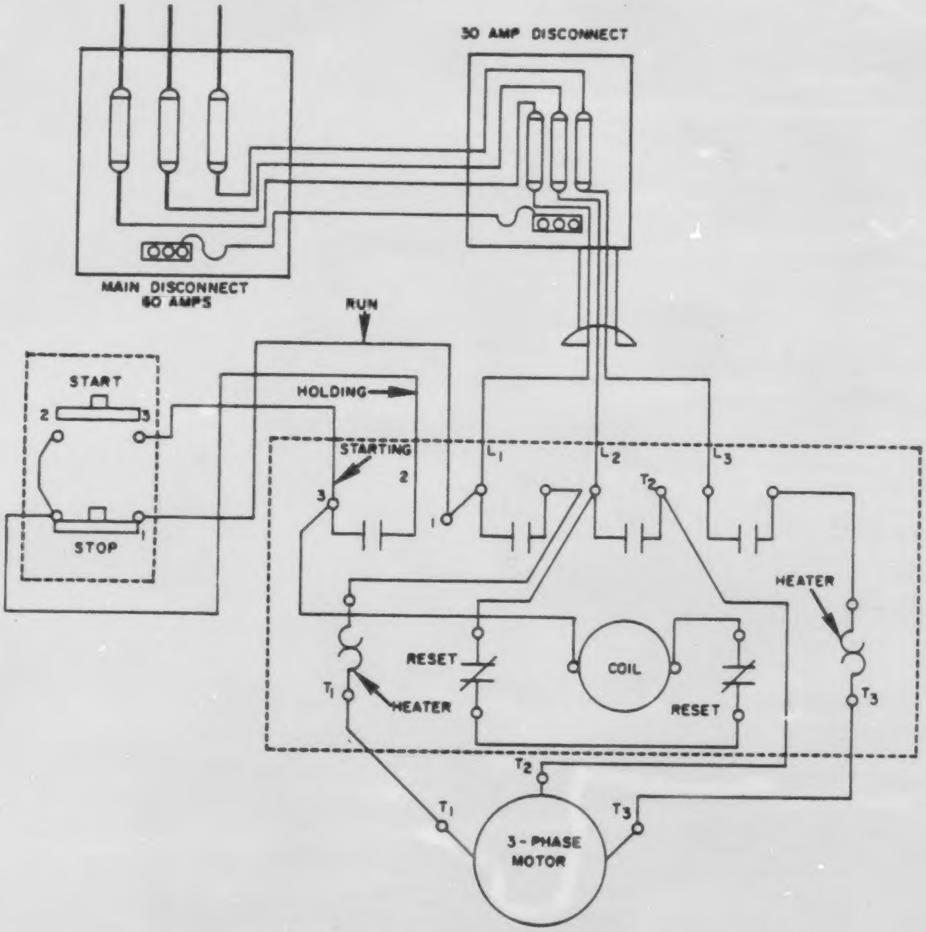

30 AMP DISCONNECT
MAIN DISCONNECT
60 AMPS
RUN
START
2
3
HOLDING
STARTING
3
2
1
STOP
1
L1
L2
L3
T2
HEATER
RESET
COIL
RESET
T1
HEATER
T3
T2
T1
T3
3-PHASE
MOTOR

Figure 30. Three-Phase Square D Starter Connected to a Three-Phase Motor

Check for continuity between the starter terminals, T1, T2, and T3 and the motor terminals, T1, T2, and T3. If we have power to the motor terminals it will be necessary to check the stator of the motor for an open circuit. This is done in a wye connected motor, as shown in figure 31.

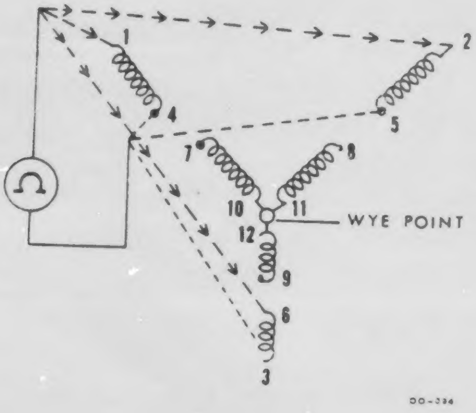


Figure 31. Testing the Stator of a Three-Phase Wye Connected Motor for an Open Circuit

Disconnect the motor leads from the power leads. Check for continuity between leads 1 and 4, 2 and 5, 3 and 6. Continuity should exist when testing across the above mentioned pairs. Since the opposite ends of leads 7, 8, and 9 are connected at a wye point in the wye connected motor, continuity should exist between leads 7 and 8, 7 and 9, or a combination of 7, 8, and 9.

Checking the stator of a dela connected, 9 lead motor for an open circuit is accomplished as shown in figure 32. Disconnect the motor leads from the power leads. Check for continuity between leads 4 and 9, 6 and 8, 5 and 7. This will check all the windings in the delta motor, inasmuch as lead 10 is connected internally to lead 2, lead 11 to lead 3, and lead 12 to lead 1, as shown in figure 32.

There is little likelihood that a squirrel-cage rotor will be open. If an open does exist, the motor slows down under load. It also has low starting torque. Signs of heating are usually evident. Fractures in the rotor bars are usually found either at the connection to the end rings or at the point the bars leave the laminations. If the motor has a wound rotor, it may be necessary to check it for an open circuit by using the external growler.

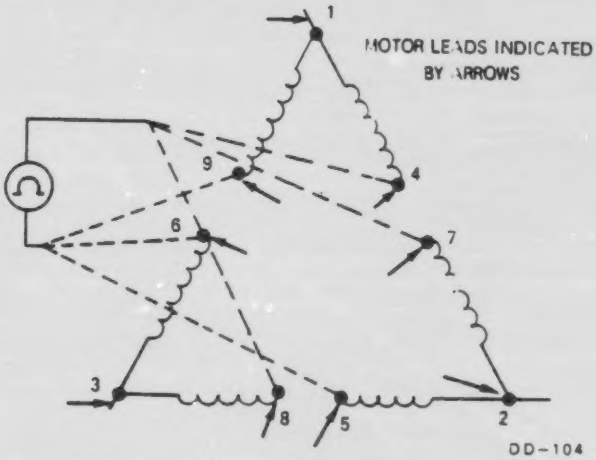


Figure 32. Testing a Delta-Connected Motor for an Open Circuit

Grounded Circuits

The same methodical process must be followed in finding a grounded circuit as was employed in finding an open circuit. It is necessary to start with the source of power and work toward the motor. With the main disconnect open, check with an ohmmeter across each power phase to ground. Follow this step all the way to the starter, to insure that no grounds exist from the source of power to the starter. Any grounds existing in the power supply or any extremity connected to L1, L2, or L3 of the starter will be indicated at any point tested, between the power source and the starter by the needle movement on the ohmmeter. This is assuming any disconnects between the source of power and the starter are closed. Disconnection of conductors at certain points will be necessary to isolate the grounded circuit. Check across each of the conductors, one at a time, connected to the start-stop station to ground (conduit), to determine if a ground exists to the start-stop station.

Check throughout the starter at points of possible grounds, the control circuit (through the coil) and the main circuit. In checking T1, T2, and T3 of the starter to ground, it must be remembered any grounds existing in the connected motor will be indicated at these points. Whether the ground exists in the motor or on the conduit can be determined by disconnecting the motor from the starter. If the ground does not exist in the conduit from the starter to the motor, the motor windings must be checked for grounds.

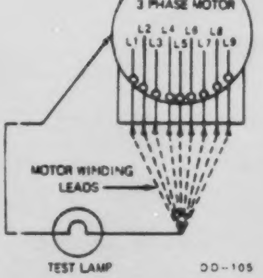


Figure 33. Testing Motor Leads for Grounded Windings

The motor windings are tested for grounds, as shown in figure 33. Position one test prod to the motor housing, being certain metal-to-metal contact has been established.

With the other lead, touch each stator lead in succession. If the needle moves, a ground is indicated. The motor must be disassembled and each phase disconnected, as shown in figure 34, and checked to ground.

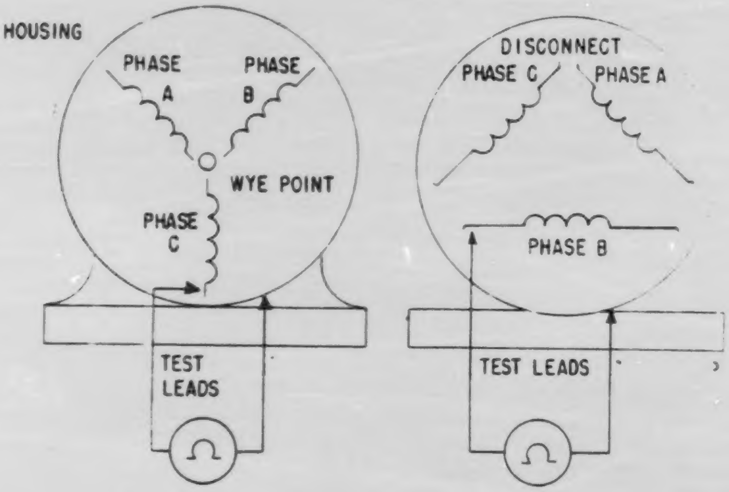

HOUSING
PHASE A
PHASE B
WYE POINT
PHASE C
TEST LEADS
DISCONNECT
PHASE C
PHASE A
PHASE B
TEST LEADS

Figure 34. Disconnection Points in Wye and Delta-Wound Motors

When the grounded phase is located, disconnect each winding group of the phase, as shown in figure 35, and check each group separately until the grounded winding groups is located. After locating the grounded winding, check to see if the trouble can be readily repaired. If not, the motor must be replaced with a serviceable one.

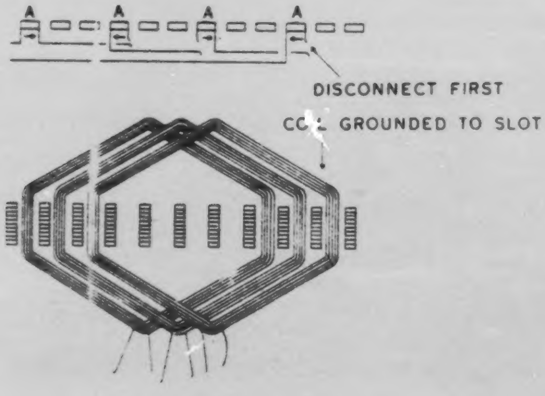

A
A
A
A
DISCONNECT FIRST
COIL GROUNDED TO SLOT

Figure 35. Disconnecting Leads Between Groups of Windings of Each Phase

A ground in the rotor of a wound motor does not affect motor performance, until a second ground occurs, in which case it will then assume the characteristics of a shorted rotor.

Shorted Circuits

Shorted circuits are found by checking across conductors with the power off. If continuity exists across two conductors when the circuit is purposely open, the circuit is shorted. As in checking for opens and grounds, checking for shorted circuits should start with the source of power and be carried through to the motor windings. Figure 36 may be used for applying tests for shorted circuits. With the main disconnect open, start by checking across the fuses (bottom end). Assuming any disconnects are closed between the source of power and the starter, continuity across any two conductors will indicate a short circuit exists between the main disconnect and the starter. Disconnection of conductors at certain points will be necessary to isolate the shorted circuit. Press the stop button and check across the conductors number 2 of starter switch to L1 or (C1). Pressing the stop button on the start-stop station opens the circuit to the starter. A continuity reading would then indicate a shorted circuit in the holding part of the circuit.

> NOTE: This circuit is normally closed due to the construction feature of the start-stop station.

Continuity across L1 or (C1) to number 3 in the starter would indicate a shorted circuit in the starting part of the circuit.

> NOTE: This circuit is normally open due to the construction feature of the start-stop station.

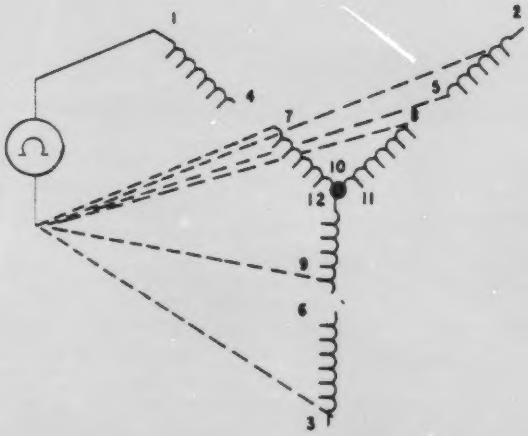


Figure 36. Testing a Wye Wound Stator for a Shorted Circuit

When checking across the T numbers, (T1, T2, or T3) it will be necessary to disconnect the motor leads from the source of power, otherwise there will be a continuity reading, due to reading across the motor windings. After disconnecting the motor leads continuity will exist when checking across T1, T2, and T3 and a short circuit exists in the conduit between the motor and the starter.

Checking a wye wound motor for a shorted stator winding is accomplished, as shown in figure 36.

The ohmmeter will be used to check across the stator leads of the motor where continuity should not exist. Continuity should exist between leads 1 and 4, 2 and 5, 3 and 6, and the leads of which the other ends form the wye point. The external leads involved in the wye are: leads 7, 8, and 9. Therefore, in testing for a shorted stator, if continuity should exist between any combination of lead numbers other than those which form a winding, a shorted stator is indicated.

Procedures for checking a delta-wound, 12-lead motor for a shorted stator winding is accomplished, as shown in figure 37.

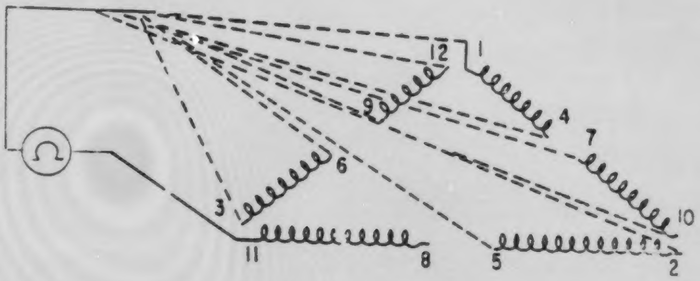


Figure 37. Testing a 12-lead, Delta-Wound Stator for a Shorted Circuit

Continuity should exist across the following leads of a delta-wound stator having 12 external leads: 1 and 4, 2 and 5, 3 and 6, 7 and 10, 8 and 11, 9 and 12. Therefore, in testing for a shorted stator, if continuity should exist between any combination of numbers other than those shown above, the stator is shorted.

Procedures for checking a 9-lead, delta-wound motor are shown in figure 38. In the 9-lead delta motor, which is most commonly used, three winding ends are internally connected. Number 12 is connected to number 1, number 11 to number 3, and number 10 to number 2. Continuity should exist across leads 4 and 9, 6 and 8, 5 and 7. Therefore, in testing for a shorted stator, if continuity should exist between any combination other than those shown above, providing leads 1, 2, and 3 are not used, the stator is shorted. Leads 1, 2, and 3 are not used because internal leads 12, 10, and 11 are connected to them.

One of the characteristics of a squirrel-cage rotor is that it is shorted. However, if the motor has a wound rotor it may be necessary to check it for a shorted circuit. It can be checked by using the external growler.

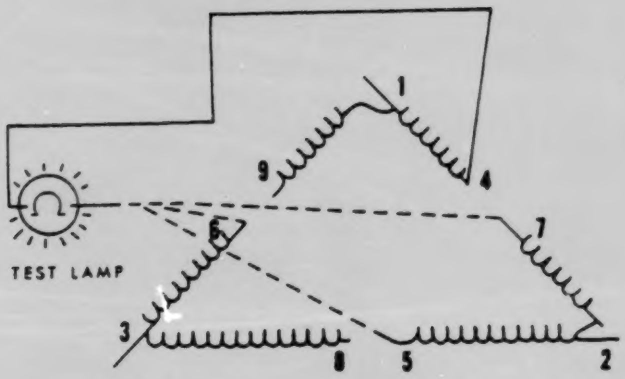


Figure 38. Testing a 9-Lead Delta-Wound Stator for a Shorted Circuit

INSPECTION PRIOR TO REPLACEMENT OF MOTOR

Motor troubles can sometimes be determined by visual inspection. Before actual disassembly of a motor, wipe all excessive dirt and grease from the surfaces with a clean cloth, moistened with a safety type solvent such as technical trichloromethane (methyl chloroform).

CAUTION: Provide adequate ventilation both during and after use.

Avoid prolonged inhalation of vapor, since this cleaner has a drying effect on the skin.

Inspect the leads for burned, cracked, or unserviceable insulation, particularly at the point of entry into the motor. Inspect the endbells for cracks and mismatch of mating surfaces.

If the trouble cannot be detected by any of the methods listed, the motor insulation should be checked for breakdown.

Insulation tests are made to determine condition, rather than quality of insulation; the tests indicating presence of moisture, dirt, or carbonized material without breaking down the insulation are the most satisfactory. The service test most generally applied to electrical apparatus is determination of the insulation resistance.

Megohms of resistance between winding and ground indicate insulation condition if a comparison with several previous readings is made to determine improvement or deterioration. All readings should be taken under the same conditions with the machine at normal working temperature. If tests are not made under the same temperature and humidity conditions, the insulation resistance will vary. The temperature and humidity must be recorded at the time the insulation resistance tests are made. Standards of the American Institute of Electrical Engineers (AIEE) establish the normal insulation-resistance value (at approximately 75°C) as follows:

220-volt motor--0.2 megohm
440-volt motor--0.4 megohm

A megohmmeter is normally used to test the insulation of a group fo coils or of the whole motor.

A megohmmeter is a self-contained instrument giving a direct reading of insulation resistance. Before using a megohmmeter, connect the leads from the ground terminal and the line terminal together and turn the handcrank until the clutch slips: the indicator should read "0." Separate the leads and turn the handcrank again. The reading should be infinity (∞). This test indicates that the meter is operating correctly.

To use this instrument connect the LINE binding post of the megohmmeter to a line terminal of the motor, then connect the GROUND binding post to the frame of the motor and to ground, as shown in figure 39. Turn the crank of the megohmmeter (megger) fast enough to cause the centrifugal clutch to slip. (The slipping of the clutch assures the operator that the proper voltage (500 volts) is being developed, and at the same time protects the instrument against overload due to excessive generator speed.) Note the position of the pointer over the indicator scale. The scale reads directly in megohms. Be sure the eye is directly over the scale and pointer to avoid errors in reading the scale. Test each line terminal of the motor and compare the readings.

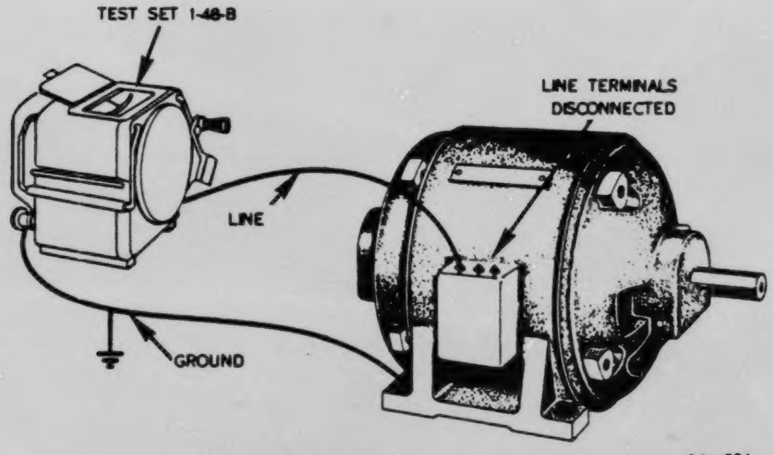


Figure 39. Megohmmeter

PROCEDURES FOR CORRECTING MALFUNCTIONS

All malfunctions in motors and controls may be corrected by the Air Force electrician except malfunctions in the internal wiring of the motors. Common malfunctions are:

- Motor does not start
- Motor runs hot
- Motor stops running

- Motor operates with excessive noise
- Motor runs slowly

Motor Does Not Start

The motor may not start due to a voltage failure. Check the line voltage. Check for blown fuses, broken or loose connections. Any bad conductors should be replaced.

Motor Runs Hot

The motor may be operating under an overload. Check the full load amperage against the data plate rating. Check the rating of the overload relay against the full load current. If the rating of the relay is too high, replace it with the proper rated relay.

Check the available voltage to be sure the motor is not operating on, under, or over voltage. It may be necessary to lighten the load or install a larger motor.

Check for proper motor and power connections. Be sure the motor is properly connected to the available voltage.

Check for proper ventilation. Clean any dirt from around vents or windings.

Check the motor to determine if it has been properly lubricated. If it has not been, oil it according to the manufacturer's instruction.

The motor may overheat due to starting too frequently. Determine if the motor is rated for intermittent duty. If it is not rated for the service required, replace it with one of proper design.

Motor Stops Running

If the motor stops running, sufficient time should be allowed for the motor control to cool. The reset should be pushed into locked position and the start button pushed in. If the motor starts, close observation should be maintained until the operator is sure the motor failure was not due to any severe circumstance, the recurrence of which would result in serious damage to the motor. A brief overload or a power failure may have been the cause of the failure. Occasionally the relay must be replaced due to it becoming faulty. If the motor cannot be restarted, it may be necessary to recheck all the things previously discussed under the topic "Procedures for Correcting Malfunctions."

Motor Operates with Excessive Noise

Excessive noise may result from the motor not being securely mounted. This condition may be remedied by tightening the mounting bolts and the motor support securely.

Dry motor bearings may cause excessive noise while the motor is in operation. Proper lubrication may stop the excessive noise, providing permanent damage has not been sustained by the bearings. Sufficient damage to the bearings may require the bearings be replaced. A regular lubricating schedule should be followed. Be certain the lubricant is the type suggested by the motor manufacturer.

Loose rotor bars may cause excessive noise. This condition requires the bars be soldered or welded to the end rings.

Excessive noise may be the result of loose motor accessories. It may be eliminated by tightening the oil well cover and the connection box cover.

The motor may not be mounted on a solid surface. Replacing the mounting surface may quiet the operation of the motor.

Motor Runs Slowly

When a motor runs slower than it is rated to run, considering slip in induction motors, several factors should be considered. The motor may be overloaded. Satisfactory service cannot be obtained unless a larger motor is installed.

The voltage supply may be deficient, causing a motor to run too slow. Correct the supply voltage. The voltage must be within 10 percent of the voltage rating for the motor.

The bearings of a motor may be binding which will cause the motor to run at less than rated speed. The bearings should be replaced if needed. Cleaning and relubrication may correct the trouble.

The driven machine may cause a motor to run slowly. When it is suspected that the driven machine is at fault, the motor should be disconnected from its load and tested independently of the machine.

Occasionally a rotor may be open. This will result in the motor slowing down under load. The rotor must be repaired or replaced.

SUMMARY

The Air Force electrician is responsible for minor adjustments and maintenance of motors and controls. He should be aware of the troubles that may occur in motors and controls, how certain troubles will affect the operation of the equipment and how to correct the trouble when it arises.

The most common operational troubles will be: overloads,failures of power, frozen or worn bearings, bad connections, and difficulties arising as the result of the driven machine.

Circuit faults will arise from time to time. They must be dealt with in a methodical manner. As always in locating circuit faults the electrician should start with the source of power and work through to the motor. By following good work practices, the Air Force electrician will be able to put the equipment back in service with the minimum loss of time.

If a motor cannot be repaired and returned to service without complete disassembly it must be replaced with a serviceable one or turned into a motor shop for repair.

Usually the source of trouble can be detected by visual inspection. In testing for open, grounded, or shorted windings an ohmmeter may be used.

QUESTIONS

1. What instrument is used to check insulation resistance?
2. How does insufficient line voltage affect the operation of a motor?
3. How can it be determined whether the driven machine or the motor is responsible for an overload?
4. If a motor shaft does not turn easily by hand, what is the probable cause?
5. What are three things that may cause a motor to run hot?
6. How is a grounded winding detected in a motor?
7. How can excessive end play of a rotor shaft be corrected?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electric Motors

Rosenberg's Electric Motor Repair

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Department of Civil Engineering Training
Sheppard Air Force Base, Texas 76311

SG 3ABR54230-1-IV-3
July 1975

SINGLE-PHASE MOTOR SYSTEMS

OBJECTIVE

To enable you to understand the fundamentals, connections, and uses of single-phase motor systems.

INTRODUCTION

An electric motor is defined as a rotary machine which converts electrical energy into mechanical energy. To be able to properly connect, control, operate, and maintain single-phase electric motors, it is necessary that you know the fundamentals by which they operate. This study guide was developed to aid you in understanding single-phase motors and single-phase motor control systems.

INFORMATION

SECTION 1
FUNDAMENTALS OF SINGLE-PHASE MOTORS

Motors may be classed according to their construction features. The two general classes to be covered in this study guide are the commutator motors and induction motors. Both of these classes of motors have a stationary field which is energized with alternating current.

Induction Motors

SPLIT-PHASE MOTORS. Split-phase motors are usually just fractional horsepower and are used to operate such devices as washing machines, small pumps, dryers, and blowers.

Basically, a split-phase motor is constructed the same as a three-phase motor. It has a stator, rotor, and two endbells. The windings are located and connected differently than they are in a three-phase motor. A centrifugal switch has been added to the rotor and one endbell. See figure 40. A rotating part of the centrifugal switch is located on the rotor and a stationary part (containing a set of contacts) is located in the endbell. The purpose of this switch will be explained later in this study guide.

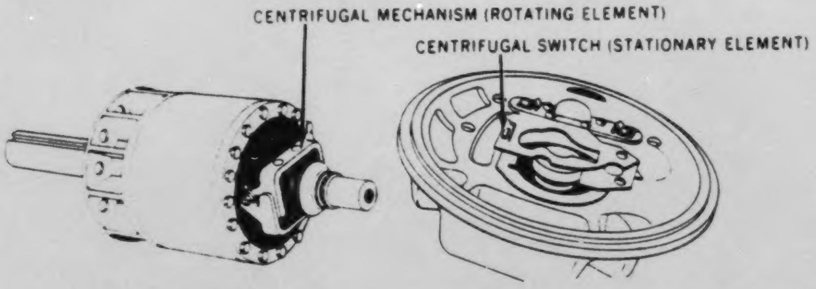

CENTRIFUGAL MECHANISM (ROTATING ELEMENT)
CENTRIFUGAL SWITCH (STATIONARY ELEMENT)

Figure 40. Components of Centrifugal Switch

WINDINGS. The split-phase motor has two windings. One winding is of heavy insulated copper wire, which is generally located at the bottom of slots in the stator and are called "Run Windings" or Main Windings." The other winding is called the "Start Winding" and is generally located in the stator on top of the run winding. The start winding and the run winding are connected to power until the motor reaches 75 percent of its maximum RPM. The centrifugal switch disconnects the start winding from the power. The run winding is made up of many turns of heavy copper wire and the start winding is made up of fewer turns of small wire. If the start winding was not disconnected after a short period of time, it will burn up.

CENTRIFUGAL SWITCH. The rotating part of a centrifugal switch is a mechanical mechanism that relies on motion and flyweights to operate. As the rotor turns the flyweights are pulled out by centrifugal force. This applies pressure to the closed contacts of the switch causing them to open. These contacts are in series with the start winding. The opening of the contacts will deenergize the start-winding. See figure 41.

OPERATION. When a split-phase motor is started, current flows through both the running and the starting winding. This causes a magnetic field to be formed inside the motor. The magnetic field induces a current in the rotor windings, which, in turn, causes a magnetic field in the rotor. The magnetic fields combine in such a manner as to cause rotation of the rotor. The start winding is necessary at the start in order to produce the rotating field effect. After the motor is running, the start winding is no longer needed and is cut out of the circuit by means of the centrifugal switch. After the start windings are cut out, the motor operates on a shifting magnetic field.

Capacitor Motors

Capacitor motors are made in sizes ranging from 1/20 to 10 horsepower. They are widely used to operate refrigerators, washing machines, air compressors, air conditioners, and fans.

A capacitor motor is constructed similarly to a split-phase motor. A capacitor has been added to give the motor better starting torque.

CAPACITOR-START MOTOR. A capacitor-start motor is an improved version of the basic split-phase type motor. An intermittent type of capacitor is connected in series with the start winding. When the motor reaches 75 percent of full speed, the centrifugal switch cuts out the start windings and the capacitor. The capacitor added in the start windings gives the motor a greater starting torque than a basic split-phase motor.

To create a starting torque in a capacitor motor, a better rotating magnetic field has to be established inside the motor. This is accomplished by placing the starting winding out of phase with the running windings by more electrical degrees. A capacitor is used to cause the current in the start winding to reach its maximum value before the current in the running winding becomes maximum. Actually, the capacitor causes the current in the start winding to lead the current in the running winding. This causes a revolving magnetic field in the stator which induces a current in the rotor and causes it to rotate.

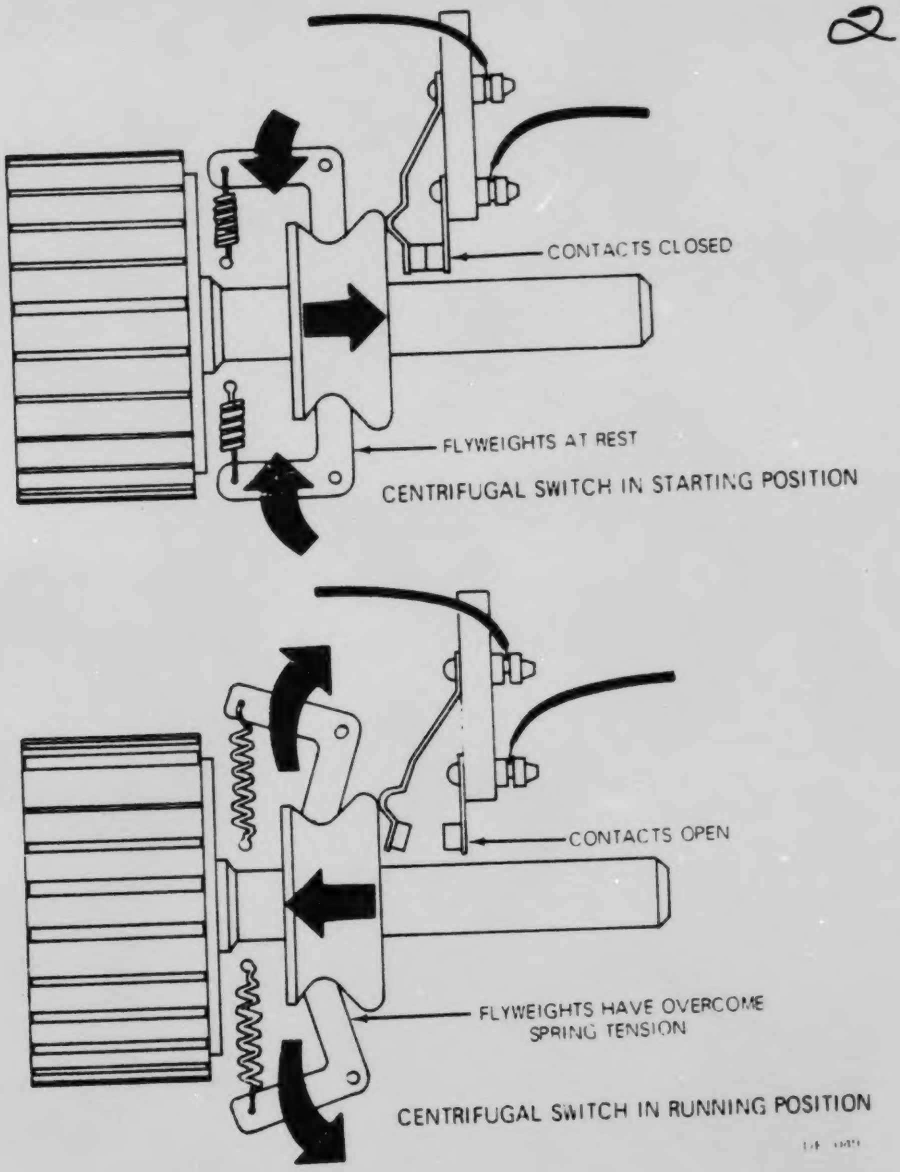

CONTACTS CLOSED
FLYWEIGHTS AT REST
CENTRIFUGAL SWITCH IN STARTING POSITION
CONTACTS OPEN
FLYWEIGHTS HAVE OVERCOME SPRING TENSION
CENTRIFUGAL SWITCH IN RUNNING POSITION

Figure 41. Centrifugal Switch

PERMANENT-SPLIT CAPACITOR MOTOR. The permanent-split capacitor consists of a standard split-phase type stator, a squirrel-cage rotor, a capacitor and endbells. This is another version of the basic split-phase motor. A permanent type capacitor is connected in series with the starting windings and left in the circuit at all times. The starting windings in this motor are not a high resistance winding and have the same number of turns and wire size as the run windings. The capacitor is used instead of resistance to give the split-phase effect. This eliminates the need for a centrifugal switch in this motor. The capacitor is continuously rated and is selected to give best operation at full speed while sacrificing starting torque. The permanent-split capacitor motor has the operating characteristics of poor starting torque with a high current draw, but runs with a good torque under load, at a constant speed.

Commutator Motors

Single-phase commutator motors have a drum-wound armature, commutator, and brushes. This study guide will cover the simple replusion, repulsion start-induction run, repulsion induction, and universal.

SIMPLE REPULSION MOTOR. The simple repulsion motor consists of a single concentric type stator, a wound rotor, a commutator, two carbon brushes, compensating windings, and endbells. The stator windings and the compensating windings are connected in series. The compensating windings are used to improve the power factor in this motor. Two carbon brushes are employed on the commutator. The two brushes are short-circuited to each other. This motor has the operating characteristics of high starting torque and low starting current draw. Although its starting torque is useful, its large variation of speed with load is not desirable in many applications. This motor is commonly made in sizes from 1 to 10 horsepower and is used to power such load as conveyors, small compressors and woodworking equipment. The simple repulsion motor is shown in figure 42.

REPULSION START-INDUCTION RUN MOTOR. The repulsion start-induction run motor consists of a single concentric type stator, a wound rotor, compensating windings, a centrifugal device, and endbells. This type of repulsion motor uses four carbon brushes; two are short-circuited together, the other two brushes are connected in series with the compensating winding. The compensating windings in this motor are used to improve the power factor during the starting period. The centrifugal device used in this motor consists of a shorting ring and a brush lifting mechanism. As the motor reaches approximately 75 percent of its rated speed, the centrifugal device forces the short-circuiting ring into contact with the inner surface of the commutator segments and converts the motor into an induction motor. At the same time, the centrifugal mechanism raises the brushes, which reduces wear of the brushes and commutator. This motor has the operating characteristics of high starting torque with a low current draw and a constant running speed under load. The repulsion start-induction run motor, shown in figure 43, is made in sizes from 1/4 to 10 horsepower and is used to power such loads as compressors, fans, pumps, stokers, and farm machinery.

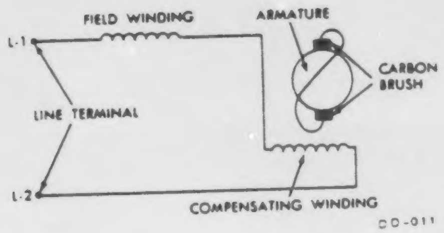

FIELD WINDING
ARMATURE
L-1
CARBON BRUSH
LINE TERMINAL
L-2
COMPENSATING WINDING
OD-011

Figure 42. Schematic Wiring Diagram of a Single-Phase Repulsion Motor

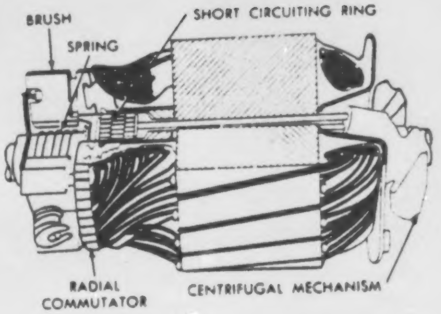

BRUSH
SPRING
SHORT CIRCUITING RING
RADIAL COMMUTATOR
CENTRIFUGAL MECHANISM

Figure 43. Repulsion-Start Induction-Run Motor Rotor

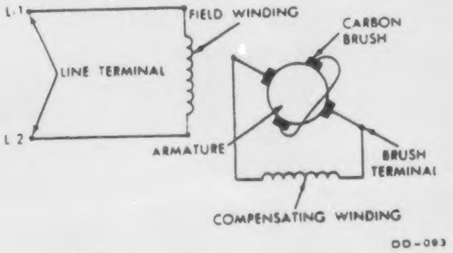

L-1
FIELD WINDING
CARBON BRUSH
LINE TERMINAL
L 2
ARMATURE
BRUSH TERMINAL
COMPENSATING WINDING
OD-093

Figure 44. Schematic Wiring Diagram of a Single-Phase Repulsion-Induction Motor

REPULSION-INDUCTION MOTOR. The repulsion-induction motor consists of a single concentric type stator, a combination rotor, a commutator, brushes, compensating windings and endbells. This type of motor has four carbon brushes, two being short-circuited together: the other two brushes are in series with the compensating windings. The compensating windings in this motor are used to improve the power factor of the motor and to reduce some of the sparking at the brushes. This motor does not have a centrifugal switch or device but instead has a squirrel-cage winding on its rotor in addition to a wound rotor. Rotors of this type are called combination rotors. The squirrel-cage winding is placed underneath the wound rotor section and is so constructed as to have high-inductive reactance. At low speeds, very little current flows in the squirrel-cage windings and the motor starts as a repulsion motor. When the motor reaches operating speed, the frequency of the induced rotor currents is low, so that current flows more in the squirrel-cage winding and the motor operates as an induction motor. This motor has the operating characteristics of high starting torque with a low current draw and a constant running speed under load. The major disadvantage of this motor is that the brushes remain on the commutator, causing arcing, thus increased maintenance. The repulsion-induction motor shown in figure 44 is made in sizes up to 10 horsepower and is used to power such loads as printing presses, textile machines, and laundry extractors. To reverse the direction of rotation the brushes must be shifted past the neutral plane.

Universal Motor

A universal motor is one that can operate on either single-phase alternating current or direct current. These motors are normally made in sizes ranging from 1/200 to 3/4 horsepower. They are obtainable in much larger sizes for special conditions. The fractional horsepower sizes are used on vacuum cleaners, sewing machines, food mixers, and power handtools. There are several types of universal motors: however, the salient pole type is more popular than the other types.

300

The salient pole type consists of a stator with two concentrated field windings, a wound rotor, a commutator, and brushes. The stator and rotor windings in this motor are connected in series with the power source. Two carbon brushes are employed in this motor and remain on the commutator at all times. These two brushes are used to connect the rotor windings in series with the field windings and the power source. See figure 45.

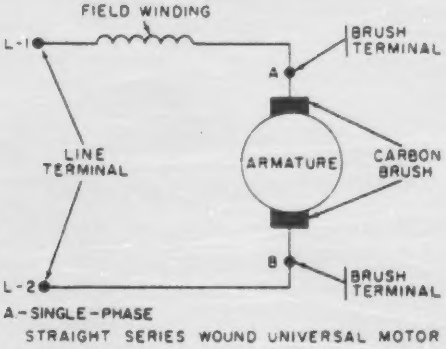


Figure 45. Universal Motor

The universal motor does not operate at a constant speed. The motor runs as fast as the load permits--low speed with a heavy load and high speed with a light load. Universal motors have the highest horsepower to weight ratio of all of the types of electric motors.

SUMMARY

To develop skill and proficiency in the connecting, operating, and maintaining single-phase motors, you should know as much about them as possible.

The various types of single-phase motors are capacitor start, split-phase, universal motors, and repulsion motors. All of these motors operate on the principle of interaction between magnetic fields. The major difference between single-phase motors is usually in the method used for starting. Capacitor start motors, of course, employ the use of a capacitor to throw the starting current out of phase with the running current. This acts to shift the magnetic fields acting on the motor rotor to provide starting torque. Universal motors have a wound rotor the same as a direct current motor but they are designed to operate both on ac and dc. Split-phase motors have a separate starting winding which serves to affect the necessary phase shift for starting.

QUESTIONS

1. What is the purpose of the capacitor on a capacitor motor?

2. Split-phase and capacitor motors have what type of rotor?

3. How is a repulsion-induction motor reversed?
4. Universal motors are commonly used for what type of loads?
5. Which induction motor discussed does not have a centrifugal switch?
6. Which motor uses a centrifugal device?
7. Two classes of single-phase motors are __________________ and _____________.
8. What purpose does the centrifugal switch have?
9. Which motor has power to both the rotor and stator?
10. Compensating winding is used for what purpose?

REFERENCE

TO 34Y19-1-1, Use, Care, and Maintenance of Electrical Motors

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Electric Motor Repair, Robert Rosenberg

Electric Motor Controls, Delmar Publishers

National Electrical Code

SECTION 2
SINGLE-PHASE MOTOR CONNECTIONS

Split-phase and capacitor start motors are made for either single or dual voltage operation. The single voltage, nonreversible type will have only two leads--1 and 2. The single voltage reversible motor will have four leads numbered 1, 2, 5, and 8. A dual voltage nonreversible motor will have four leads numbered 1, 2, 3, and 4. The dual voltage reversible motor leads will be numbered 1, 2, 3, 4, 5, and 8. Leads numbered 6 and 7 are terminals of coils which are connected internally.

In order to operate a dual voltage motor on the high voltage, the running winding must be connected in series as shown in figure 46. Leads 2, 3, and 8 are connected and taped, leads 1 and 5 connect together and goes to power. Lead 4 goes to power, see figure 46.

To operate on the lower voltage, the running windings are connected in parallel. Leads 1, 3, and 5 are connected together, then to power. Leads 2, 4, 8 connect together, then to ground, see figure 47.

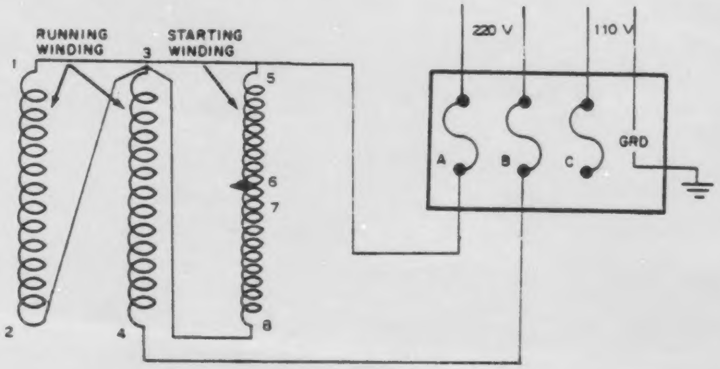


Figure 46. Schematic of Single-Phase Motor Windings Connected for High Voltage--220 Volts

The starting winding is always connected in parallel with the running winding, regardless of which voltage (high or low) is connected to the motor. The starting winding cannot at any time have more than 120 volts across it.

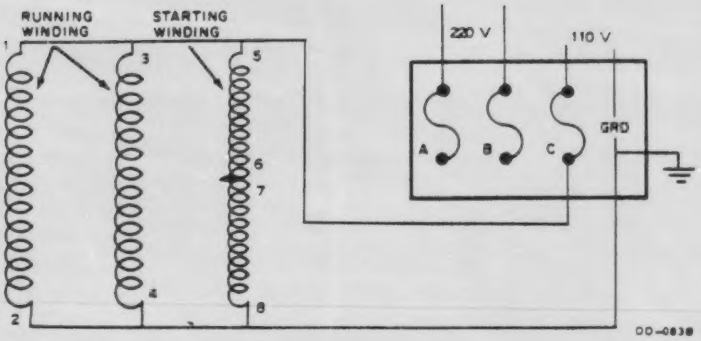

RUNNING WINDING
STARTING WINDING
1
2
3
4
5
6
7
8
220 V
110 V
A
B
C
GRD
OO-0838

Figure 47. Schematic of Single-Phase Motor Windings Connected for Low Voltage--110 Volts

To reverse direction of rotation of a single-phase induction motor, the start winding leads must be interchanged. Leads 5 and 8 are the start winding leads. High voltage would be leads 2, 3, and 5 connected together and taped. Leads 1 and 8 are connected together, then to power, and lead 4 connects to power. Figure 48 shows these connections. The same method is used for low voltage. Leads 1, 3, and 8 connect to power and 2, 4, and 5 to ground.

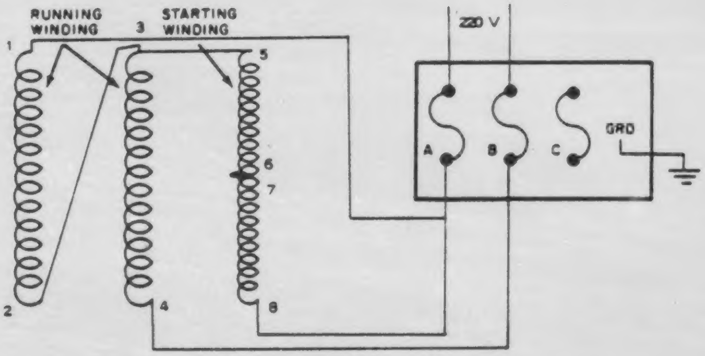

RUNNING WINDING
STARTING WINDING
1
2
3
4
5
6
7
8
220 V
A
B
C
GRD

Figure 48. Reversing Direction of Rotation of a Single-Phase Motor Connected for High Voltage

SUMMARY

Single-phase motor connections can change the operation of the motor from single-voltage, nonreversible to dual-voltage reversible. The number of motor leads will vary in number from 2 to 6 depending on its use. For high voltage the run winding and start winding are connected to form a series-parallel circuit. For low voltage the two windings are connected to form a parallel circuit. To reverse direction of rotation, the start winding leads must be interchanged.

QUESTIONS

1. Explain how the leads are connected on a split-phase motor connected for high voltage.

2. Explain how the leads are connected on a split-phase motor connected for low voltage.

3. Leads 5 and 8 are the ends of which winding in a split-phase motor?

4. How can a split-phase motor be reversed?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electrical Motors

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Electric Motor Repair, Robert Rosenberg

Electric Motor Controls, Delmar Publishers

National Electrical Code

SECTION 3
SINGLE-PHASE MOTOR CONTROLLERS

Single-phase motor controllers are constructed and operate similarly to three-phase motor controllers. Where switching in three conductors is required in three-phase motor systems, only one or two conductors require switching in single-phase motor systems.

Magnetic Line Voltage Starters

Single-phase magnetic starters have the same circuits as the three starters, (Power, Control, Load, Start, and Holding). They have only two main or load contacts and one overload protective relay. The coil in the starter is usually wound for dual voltage (120/240) and is labeled or color coded. The red lead is the common and is used with either 120 or 240 volt power connections. The white lead is used when low voltage (120 volts) connections are required. The black lead is used when high voltage (240 volts) power is required.

Figure 49 shows a single-phase magnetic starter and motor with low voltage connections. The circuits of a magnetic starter are broken down as the control circuit, figure 50 the starting circuit, figure 51 the holding circuit, figure 52 and the load circuit, figure 53.

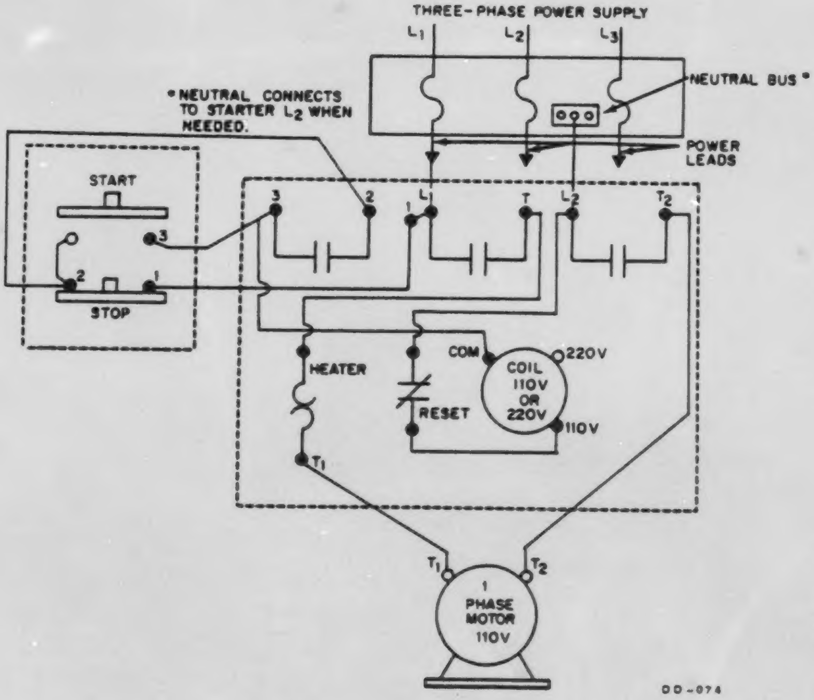

THREE-PHASE POWER SUPPLY
L1
L2
L3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L2 WHEN NEEDED.
POWER LEADS
START
3
2
1
STOP
3
2
1
L1
T
L2
T2
HEATER
COM
COIL 110V OR 220V
220V
110V
RESET
T1
T1
T2
1 PHASE MOTOR 110V
DD-074

Figure 49. Connecting a Single-Phase Magnetic Starter

The part of the magnetic starter circuit from contact 3 to coil to reset to L2 is the control circuit, as shown in figure 50.

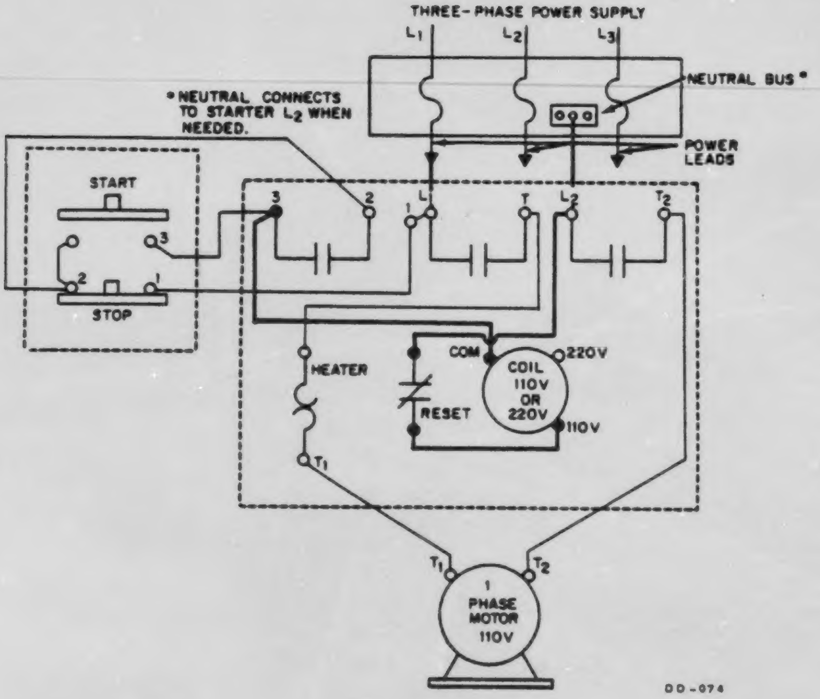

THREE-PHASE POWER SUPPLY
L_1
L_2
L_3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L_2 WHEN NEEDED.
POWER LEADS
START
STOP
3
2
1
3
2
L_1
1
T
L_2
T_2
HEATER
T_1
COM
RESET
COIL 110V OR 220V
220V
110V
T_1
T_2
1 PHASE MOTOR 110V
DD-074

Figure 50. Connecting the Control Circuit in a Magnetic Starter

The starting circuit, as shown in figure 51, is L_1 or 1 in the magnetic starter to terminal 1 on the stop button, to 2, which is the jumpered side of the stop-start station. When start button is pushed continuity is made from the jumpered side of the start button to terminal 3 and from there to 3 in the magnetic starter.

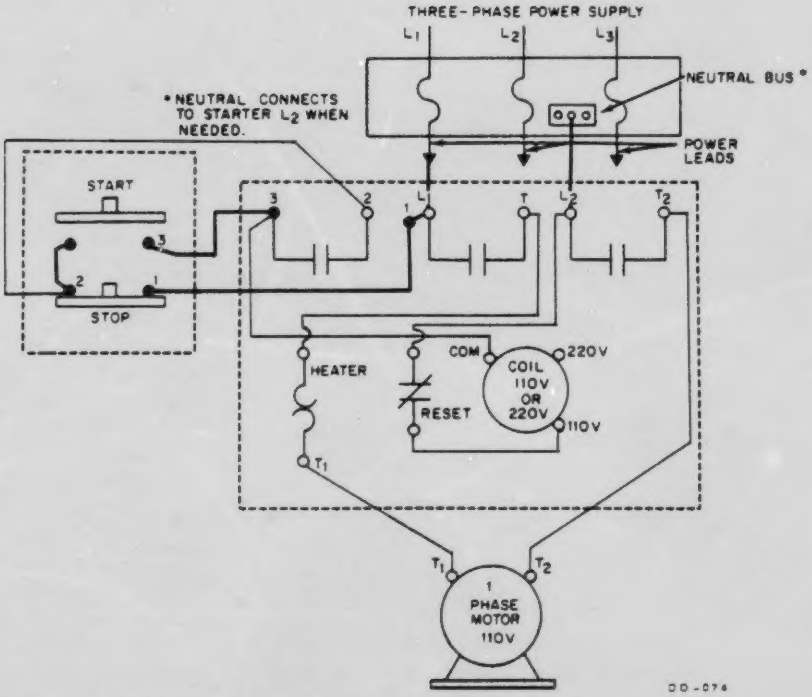

THREE-PHASE POWER SUPPLY
L_1
L_2
L_3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L_2 WHEN NEEDED.
POWER LEADS
START
3
2
1
STOP
3
2
1
L_1
T
L_2
T_2
COM
220V
HEATER
COIL 110V OR 220V
RESET
110V
T_1
T_1
T_2
1 PHASE MOTOR 110V
DD-074

Figure 51. Connecting the Starting Circuit in a Magnetic Starter

A holding circuit must be used when a start station is spring-loaded to the open position. The holding circuit is from 1 to L_2 in the magnetic starter to 1 on the stop station, across to 2 on the stop station and to 2 in the magnetic starter. Figure 52 shows this circuit.

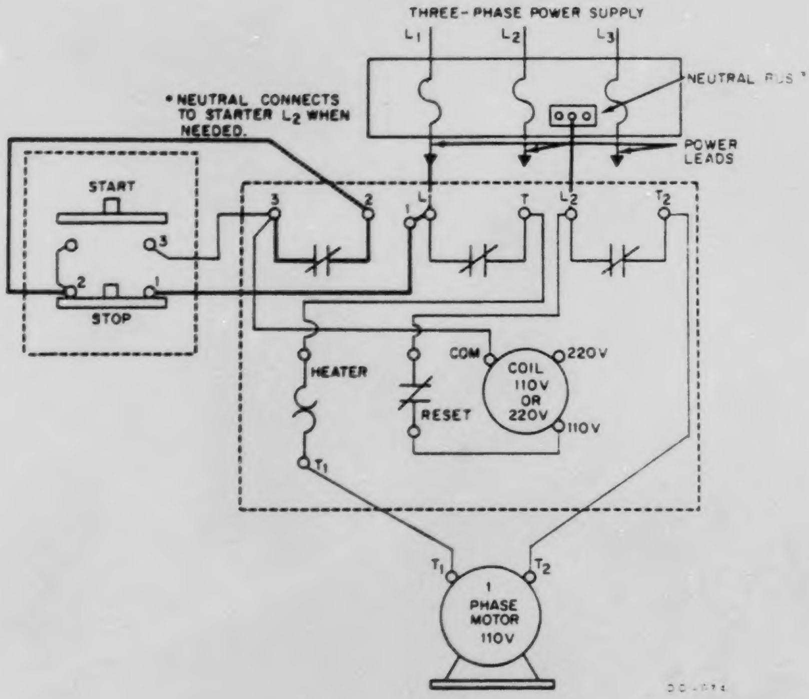

THREE-PHASE POWER SUPPLY
L1
L2
L3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L2 WHEN NEEDED.
POWER LEADS
START
STOP
3
2
1
L1
T
L2
T2
HEATER
T1
COM
RESET
COIL 110V OR 220V
220V
110V
T1
T2
1 PHASE MOTOR 110V

Figure 52. Connecting the Holding Circuit in a Magnetic Starter

The load circuit connects the motor to the power supply. From contact "T" in the magnetic starter through the heater to T_1 on the motor. The second lead of the motor (T_2) is tied directly to T_2 in the magnetic starter. The load circuit is shown in figure 53.

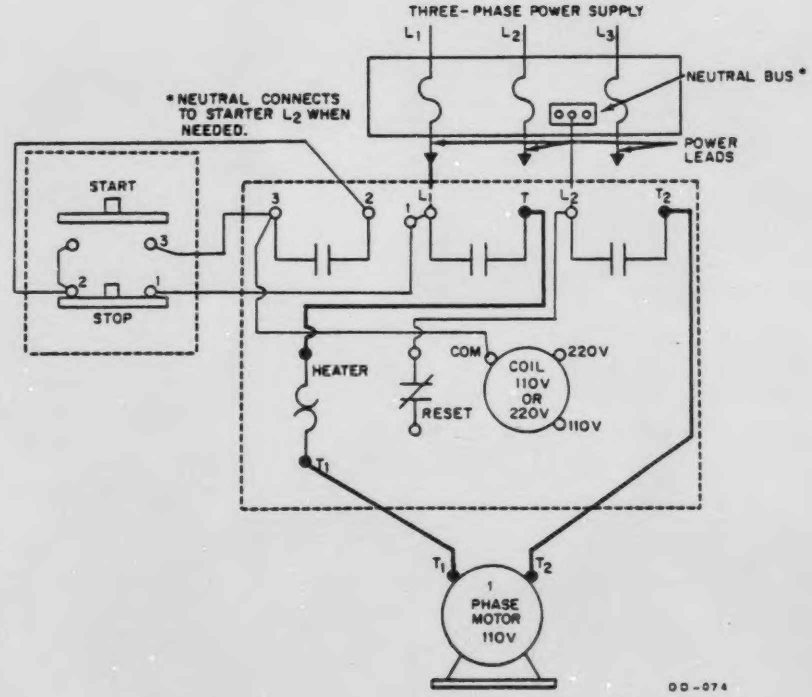

THREE-PHASE POWER SUPPLY
L_1
L_2
L_3
NEUTRAL BUS *
*NEUTRAL CONNECTS TO STARTER L_2 WHEN NEEDED.
POWER LEADS
START
3
2
1
STOP
3
2
1
L_1
T
L_2
T_2
HEATER
COM
220V
COIL 110V OR 220V
110V
RESET
T_1
T_1
T_2
1 PHASE MOTOR 110V
OD-074

Figure 53. Connecting the Load Circuit in a Starter

Drum Control

A drum controller, when used to control a single-phase motor, performs the same function as it does when controlling a three-phase motor. It starts, stops, or reverses the motor. The wiring connections are different. Figure 54 shows the wiring connections for both high voltage and low voltage.

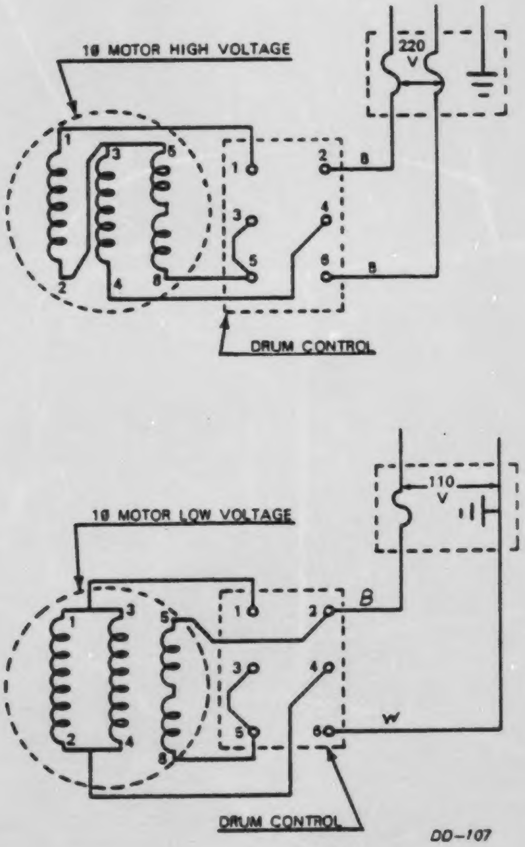

1Ø MOTOR HIGH VOLTAGE
220 V
1
3
5
2
4
8
1
2
3
4
5
6
B
B
DRUM CONTROL
1Ø MOTOR LOW VOLTAGE
110 V
1
3
5
2
4
8
1
2
3
4
5
6
B
W
DRUM CONTROL
DD-107

Figure 54. Single-Phase Drum Control

Hand-Off-Automatic Switch

A "Hand-Off-Automatic Switch" (HOA) is a three-position selector switch. By switching the selector knob from one position to the other, you can stop, manually operate, or automatically operate a motor system. See figure 55.

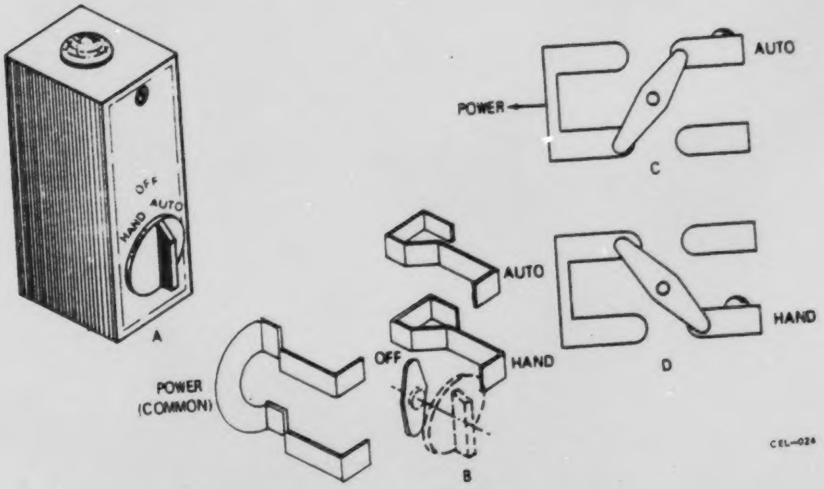

OFF
HAND
AUTO
A
POWER
AUTO
C
AUTO
HAND
POWER (COMMON)
OFF
B
HAND
D
CEL-024

Figure 55. Hand-Off-Automatic Switch

HOA switches are used in many different control systems. Figure 56 shows an example of one of the control systems where this switch is used.

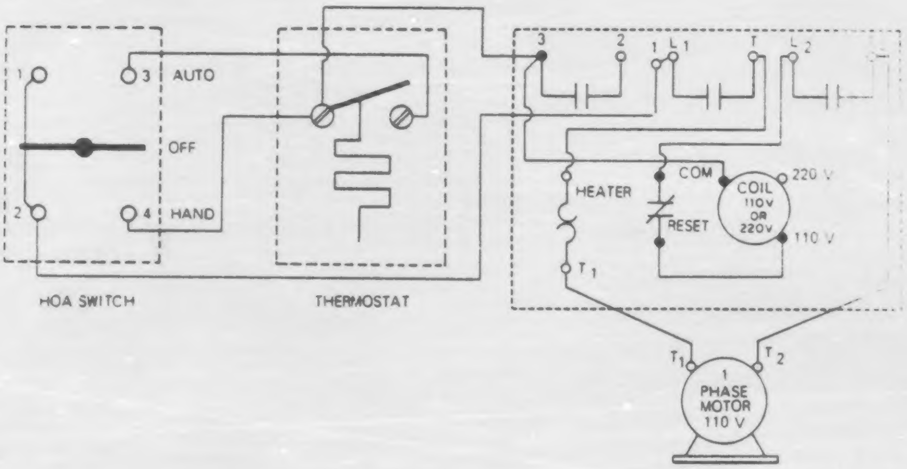

1
3
AUTO
OFF
2
4
HAND
HOA SWITCH
THERMOSTAT
3
2
1
L1
T
L2
HEATER
COM
RESET
COIL
110V
OR
220V
220 V
110 V
T1
T1
T2
1
PHASE
MOTOR
110 V

Figure 56. HOA Switch Used in Motor Control System

When the switch is turned to the automatic position, the thermostat contacts must close before the magnetic starter will energize. In the hand position the thermostat is bypassed and the magnetic starter will energize.

SUMMARY

Single-phase controls are different from three-phase in their construction features because protection and switching are not required in as many conductors. Drum controllers are used to start, stop, and reverse motors.

HOA switches provide manual or automatic control selection for control systems.

QUESTIONS

1. What is the purpose of a drum controller?

2. What is the reason for a dual voltage coil in a single-phase magnetic starter?

3. How many sets of main contacts does a single-phase magnetic starter have?

4. How many overload relays are there in a single-phase magnetic starter?

5. How many positions are there on a HOA switch?

REFERENCES

TO 34Y-1-1, Use, Care, and Maintenance of Electrical Motors

TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Electric Motor Repair, Robert Rosenberg

Electric Motor Controls, Delmar Publishers

National Electrical Code

EQUIPMENT AND SUPPLIES	Unit/Issue
SG 3ABR54230-1-IV-2	1/student

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-IV-4
July 1975

TROUBLESHOOTING SINGLE-PHASE MOTOR SYSTEMS

OBJECTIVE

The objective of this study guide is to help you become familiar with the procedures for troubleshooting, testing, maintaining, and repairing motors and motor control systems.

INTRODUCTION

Motor failure may be due to a number of causes. Some of the things that may cause motor failures are an overload, low or high voltage, frozen or worn motor bearings, failure of motor windings, and failure of motor controls.

CONDITIONS THAT CAUSE MOTOR TROUBLE

Many things that cause motor failure are not the fault of the motor. Several conditions which may cause motor failure are listed below. These conditions should be checked before disconnecting electrical powerlines or troubleshooting the electrical system.

- Overload
- Loss of Power
- Driven Machine Blocked
- Frozen or Worn Bearings
- Bad or Improper Connections

Overload

If a single-phase motor has been operating satisfactorily and suddenly stops, a temporary overload condition may exist. Sufficient time should be allowed for the overload device to cool before actuating the reset device. If sufficient cooling has occured the reset will hold in the locked position and the normal starting operation can be followed. If the motor fails to start, a systematic procedure should be employed for locating the trouble. Check current draw with an ammeter to determine if the motor is overloaded.

Loss of Power

Use a voltmeter to determine if power is being supplied to the magnetic starter. Likewise determine if power is being supplied to the motor.

Bad or Improper Connections

Before a motor is removed from the line all electrical connections should be checked. Determine if the control connections are in accordance with the control wiring diagram. When the control connections have been checked, the terminal lead connections in both the control apparatus and to the motor should be checked.

Motors with wound rotors are more susceptible to malfunctions due to their construction. Other than insulation checks which are similar to the stator winding, rotors often have opens caused by overheating and melting of the soldered connections to the commutators. Conductors must be resoldered to the segments and rebanded if necessary.

Brushes that have been worn to half their original length must be replaced. Check brushes for broken leads, chipped or broken face, correct tension, and freedom of movement in holder.

Driven Machine Blocked

Determine if the driven machine is at fault. Disconnect the motor from its load and rotate the rotor shaft of the motor by hand to determine if rotation is free. By accomplishing this, it can be determined if the driven machine is at fault.

Frozen or Worn Bearings

Try operating the motor without the load of the driven machine. Lubrication may be needed and in some cases will free the rotor. If the bearings are frozen or stuck, it may be necessary to take the motor apart to free the bearings. If the rotor shaft will turn, look for wobbling, which indicates a bent shaft. Before handling the shaft however, put on gloves, or use a piece of cloth, to insure against injury to hands from burrs or sharp edges that may be in the keyway. Check the rotor shaft for any up and down play (movement.) Any noticeable movement indicates worn bearings, which may be causing the rotor to be dragging in the stator. This is probable when belt tension is applied. The bearings should be replaced if up and down movement is noted. Also check for rotor end play. This is noted by moving rotor shaft in and out. Some end play is not detrimental; however, it should not exceed 1/64 of an inch. Excessive end play may be removed by adding fiber spacer washers.

Other things to check are: misalignment of endbells, a loose pole piece or foreign objects in the motor. If the trouble is not mechanical, the motor circuits are then analyzed.

PROCEDURES FOR TROUBLESHOOTING MOTOR SYSTEMS

All electrical circuits are subject to three common malfunctions. These circuit faults are: open, grounded, and shorted circuits.

Open Circuits

Starting with the source of power, an open circuit may exist at any point between there and the rotor of the motor. It is necessary to isolate the trouble. This must be accomplished on a step-by-step basis. Make the following checks on the equipment shown in figure 57.

Check with an ohmmeter from the source of power to the line terminals of the starter, making sure continuity exists at the starter line terminals, L1 and L2. Make sure of a continuous circuit between the start-stop station and the starter. This calls for checking the starting circuit from the starter to the switch, if the motor will not start; and the holding circuit from the starter to the switch, if the motor does not operate after releasing the start button. NOTE: THE CONDUCTOR CONNECTED TO L1 IS COMMON TO BOTH THE STARTING AND HOLDING CIRCUIT. Make sure there is a continuous path for current flow from the switch side of the starter through the holding coil and through the resets, back to L2. This circuit normally is from switch terminal 3, to starter terminal L2. Be sure you have continuity through the heaters. Raise the armature until the contacts are closed and check for continuity between L1 and T1; L2, and T2. If there are no opens to this point, power should exist to the motor terminals, T1 and T2 of the starter, when the start button is pushed.

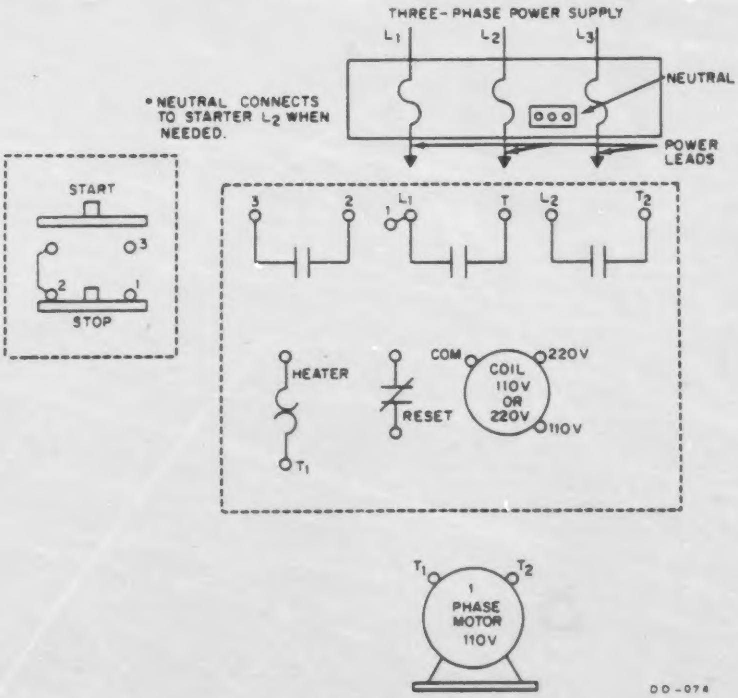

THREE-PHASE POWER SUPPLY
L1
L2
L3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L2 WHEN NEEDED.
POWER LEADS
START
STOP
3
2
1
L1
T
L2
T2
HEATER
T1
RESET
COM
220V
COIL 110V OR 220V
110V
T1
T2
1 PHASE MOTOR 110V
DO-074

Figure 57. Single-Phase Motor Control System

Check for continuity between the starter terminals, T1 and T2, and the motor terminals, T1 and T2. If we have power to the motor terminals it will be necessary to check the stator of the motor for an open circuit. This is done in a single-phase motor, as shown in figure 58.

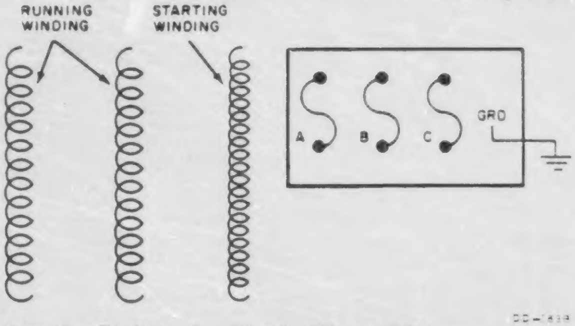


Figure 58. Testing the Stator of a Single-Phase Motor for an Open Circuit

Disconnect the motor leads from the power leads. Check for continuity between leads 1 and 2, 3 and 4, 5 and 8.

There is little likelihood that a squirrel-cage rotor will be open. If an open does exist, the motor slows down under load. It also has low starting torque. Signs of heating are usually evident. Fractures in the rotor bars are usually found either at the connection to the end rings or at the point the bars leave the laminations. If the motor has a wound rotor, it may be necessary to check it for an open circuit by using the external growler.

INSPECTION PRIOR TO REPLACEMENT OF MOTOR

Motor troubles can sometimes be determined by visual inspection. Before actual disassembly of a motor, wipe all excessive dirt and grease from the surfaces with a clean cloth moistened with a safety type solvent such as technical trichloromethane (methyl chloroform).

CAUTION: Provide adequate ventilation both during and after use.

Avoid prolonged inhalation of vapor, since this cleaner has a drying effect on the skin.

Inspect the leads for burned, cracked, or unserviceable insulation, particularly at the point of entry into the motor. Inspect the endbells for cracks and mismatch of mating surfaces.

If the trouble cannot be detected by any of the methods listed, the motor insulation should be checked for breakdown.

Insulation tests are made to determine condition, rather than quality of insulation; the tests indicating presence of mositure, dirt, or carbonized material without breaking down the insulation are the most satisfactory. The service test most generally applied to electrical apparatus is determination of the insulation resistance.

Megohms of resistance between winding and ground indicate insulation condition if a comparison with several previous readings is made to determine improvement or deterioration. All readings should be taken under the same conditions with the machine at normal working temperature. If tests are not made under the same temperature and humidity conditions, the insulation resistance will vary. The temperature and humidity must be recorded at the time the insulation resistance tests are made. Standards of the American Institute of Electrical Engineers (AIEE) establish the normal insulation-resistance value (at approximately 75°C) as follows:

220-volt motor--0.2 megohm
440-volt motor--0.4 megohm

A megohmmeter is normally used to test the insulation of a group of coils or of the whole motor.

A megohmmeter is a self-contained instrument giving a direct reading of insulation resistance. Before using a megohmmeter, connect the leads from the ground terminal and the line terminal together and turn the handcrank until the clutch slips: the indicator should read "0." Separate the leads and turn the handcrank again. The reading should be infinity (∞). This test indicates that the meter is operating correctly.

To use this instrument connect the LINE binding post of the megohmmeter to a line terminal of the motor, then connect the GROUND binding post to the frame of the motor and to ground, as shown in figure 59. Turn the crank of the megohmmeter (megger) fast enough to cause the centrifugal clutch to slip. (The slipping of the clutch assures the operator that the proper voltage (500 volts) is being developed, and at the same time protects the instrument against overload due to excessive generator speed.) Note the position of the pointer over the indicator scale. The scale reads directly in megohms. Be sure the eye is directly over the scale and pointer to avoid errors in reading the scale. Test each line terminal of the motor and compare the readings.

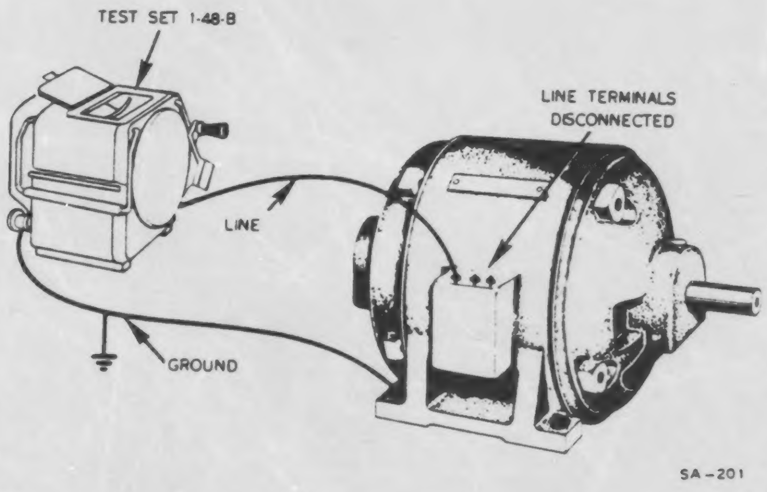


Figure 59. Megohmmeter

PROCEDURES FOR CORRECTING MALFUNCTIONS

All malfunctions in motors and controls may be corrected by the Air Force electrician except malfunctions in the internal wiring of the motors. Common malfunctions are:

- Motor does not start
- Motor runs hot
- Motor stops running
- Motor operates with excessive noise
- Motor runs slowly

Motor Does Not Start

The motor may not start due to a voltage failure. Check the line voltage. Check for blown fuses and broken or loose connections. Any bad conductors should be replaced.

Motor Runs Hot

The motor may be operating under an overload. Check the full load amperage against the data plate rating. Check the rating of the overload relay against the full load current. If the rating of the relay is too high, replace it with the proper rated relay.

Check the available voltage to be sure the motor is not operating on under- or over voltage. It may be necessary to lighten the load or install a larger motor.

Check for proper motor and power connections. Be sure the motor is properly connected to the available voltage.

Check for proper ventilation. Clean any dirt from around vents or windings.

Check the motor to determine if it has been properly lubricated. If it has not been, oil it according to the manufacturer's instruction.

The motor may overheat due to starting too frequently. Determine if the motor rated for intermittent duty. If it is not rated for the service required, replace it with one of proper design.

Motor Stops Running

If the motor stops running, sufficient time should be allowed for the motor to to cool. The reset should be pushed into locked position and the start button pushed in. If the motor starts, close observation should be maintained until the operator is sure the motor failure was not due to any severe circumstance, the recurrence of which would result in serious damage to the motor. A brief overload or a power failure may have been the cause of the failure. Occasionally the relay must be replaced due to it becoming faulty. If the motor cannot be restarted, it may be necessary to recheck all the things previously discussed under the topic "Procedures for Correcting Malfunctions."

Motor Operates with Excessive Noise

Excessive noise may result from the motor not being securely mounted. This condition may be remedied by tightening the mounting bolts and the motor support securely.

Dry motor bearings may cause excessive noise while the motor is in operation. Proper lubrication may stop the excessive noise, providing permanent damage has not been sustained by the bearings. Sufficient damage to the bearings may require the bearings be replaced. A regular lubricating schedule should be followed. Be certain the lubricant is the type suggested by the motor manufacturer.

Loose rotor bars may cause excessive noise. This condition requires the bars be soldered or welded to the end rings.

Excessive noise may be the result of loose motor accessories. It may be eliminated by tightening the oil well cover and the connection box cover.

The motor may not be mounted on a solid surface. Replacing the mounting surface may quiet the operation of the motor.

Motor Runs Slowly

When a motor runs slower than it is rated to run, considering slip in induction motors and that there is no overloading of the motor, then other factors must be considered.

The voltage supply may be deficient, causing a motor to run too slow. Correct the supply voltage. The voltage must be within 10 percent of the voltage rating for the motor.

The bearings of a motor may be binding which will cause the motor to run at less than rated speed. The bearings should be replaced if needed. Cleaning and relubrication may correct the trouble.

The driven machine may cause a motor to run slowly. When it is suspected that the driven machine is at fault, the motor should be disconnected from its load and tested independently of the machine.

Occasionally a rotor may be open. This will result in the motor slowing down under load. The rotor must be repaired or replaced.

When troubleshooting single-phase motors you should check for such items as bad centrifugal switches, bad brushes, and bad capacitors.

If a split-phase motor hums but will not start, the trouble will probably be in the centrifugal switch or bad start windings. This same problem with a capacitor start motor might mean the motor has a bad capacitor. All other checks are the same for either single - or three-phase motors.

SUMMARY

The Air Force electrician is responsible for minor adjustments and maintenance motors and controls. He should be aware of the troubles that may occur in motors and controls, how certain troubles will affect the operation of the equipment and how to correct the trouble when it arises.

The most common operational troubles will be: overloads, failures of power, frozen or worn bearings, bad connections, and difficulties arising as the result of the driven machine.

Circuit faults will arise from time to time. They must be dealt with in a methodical manner. As always in locating circuit faults the electrician should start with the source of power and work through to the motor. By following good work practices, the Air Force electrician will be able to put the equipment back in service with the minimum loss of time.

If a motor cannot be repaired and returned to service without complete disassembly it must be replaced with a serviceable one or turned into a motor shop for repair.

Usually the source of trouble can be detected by visual inspection. In testing for open, grounded, or shorted windings an ohmmeter may be used.

QUESTIONS

1. What instrument is used to check insulation resistance?
2. How does insufficient line voltage affect the operation of a motor?
3. How can it be determined whether the driven machine or the motor is responsible for an overload?
4. If a motor shaft does not turn easily by hand, what is the probable cause?
5. What are three things that may cause a motor to run hot?
6. How is a grounded winding detected in a motor?
7. How can excessive end play of a rotor shaft be corrected?
8. How will a centrifugal switch that will not reclose affect the operation of a motor?

REFERENCES

TO 34Y19-1-1, Use, Care, and Maintenance of Electric Motors
Rosenberg's Electric Motor Repair
TO 34Y19-1-102, Maintenance of Electric Motors and Generators

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-IV-5
July 1975

MOTOR GENERATORS, CONTROL PANELS, AND CIRCUIT BREAKERS

OBJECTIVE

The objective of this study guide is to help you identify the major components and understand the operation and circuit arrangement of a motor generator set and motor control centers.

INTRODUCTION

In large factories and complexes it is often desirable to provide a centralized control point for many motors required for operation. The control center serves as a housing for switches, circuit breakers, meters, transformers, contactors, and relays.

It is necessary for the electrician to be able to recognize the various components, understand how to operate a motor control center, and be able to interpret the wiring diagrams so that troubles can be eliminated without undue loss of time.

SECTION 1

MOTOR CONTROL CENTERS

Motor control centers provide an ideal means of centralizing motor control and related control equipment. They permit motor starters, feeder breakers, distribution transformers, lighting panels, interlocking relays, and metering devices to be contained in a single floor-mounted enclosure and fed from a common enclosed bus. Motor control centers are made up of standardized vertical sections housing vertical and horizontal bus, wiring channels and compartmented control units. Sections are bolted together to form a single panel assembly. Control units are mounted and wired. The entire center is powered by line connection at a single point.

Motor control centers offer grouped-control installation and operation advantages. Design flexibility--performance--safety for personnel, and equipment ease of maintenance and installation, are all contained in a motor control center.

Steel-enclosed control centers can be joined together to centralize and protect the most complex systems of auxiliary drives, or the simplest of fan or pump motor controls. Motor control centers factory mount motor starters in isolated compartments within a control center minimizing valuable floor space normally required to mount individual starters on walls or racks. Savings result from elimination of the cost of field mounting of individual starters. The costly expenses of conduit runs, pull boxes, junction boxes, and wire and cable pulling are reduced. These expenses can be controlled, and economically performed in factory assembled and tested control centers.

COMPONENTS

The following is a list of components on the face of a motor control center and their uses.

1. Control Switches - for main circuit breakers.
2. Pushbuttons - for motor control through control circuits of magnetic starters.
3. Indicating Lights - to monitor individual circuits.
4. Time Meters - record hours of operation.
5. Ammeters - to read amperage on individual phases.
6. Voltmeters - to indicate incoming voltage on individual phases.
7. Metering Switches - for phase selection.
8. Time Clock - used to turn circuit on or off at a predetermined time.

HOA Switches. HOA means Hand-Off-Auto and is used with a combination motor starter and circuit breaker. To start, move the handle to the HAND position, which also closes the magnetic motor starter contacts. Then switch the handle to AUTO and the motor will run until stopped by the opening of any pair of contacts in series with the operating circuit. You may also stop the motor by manually switching to the OFF position. HOA switches are used in the motor control center for the operation of pumps.

The electrical components located within the motor control center include circuit breakers, control transformers, contactors, and relays.

Circuit Breakers

Circuit breakers are the most common type of short-circuit protective devices. Circuit breakers offer these features: all three circuit phases trip at one time eliminating the possibility of single phasing. No replacement is normally required to reclose a circuit after a fault. Isolation and circuit protection are provided in one device.

To protect against damage from short circuits, a control center must have the capacity to withstand and successfully interrupt the maximum short-circuit current available at the incoming line terminal. To provide protection a circuit breaker can be used as a main protective device. When a circuit breaker is used as the main protective device, it is important that an instantaneous trip be provided for protection of the control center bus and power wiring. An instantaneous trip is required to remove the control center from the line quickly should a bus fault occur.

Two types of circuit breakers used in low-voltage controllers are molded case circuit breakers and switchgear type power circuit breakers. These breakers have adjustable trips and visible contacts, and are available in both stationary and drawout construction. The molded case circuit breaker is thermal-magnetic type with adjustable instantaneous trip. Operating handle integral with breaker indicates breaker position whether door is open or closed. Handle can be padlocked in off position.

Control Transformers

These are used to step down 480 volts to 120 volts for use in control circuits. Each transformer is protected from short circuits and overloads by cartridge fuses.

Contactors

Magnetic type contactor with built-in overload protection. Controlled by HOA switches, float switches, thermostats, etc. Usually 110V control voltage and 220/440 volts operation.

Relays

For control, may be pull-in, drop-out, or time delay.

CIRCUITRY

Figures 60, 61, and 62 are diagrams of typical control centers. Study these diagrams carefully. The instructor will discuss each of these diagrams.

Failure to close breakers and switches in proper sequence will prevent proper operation.

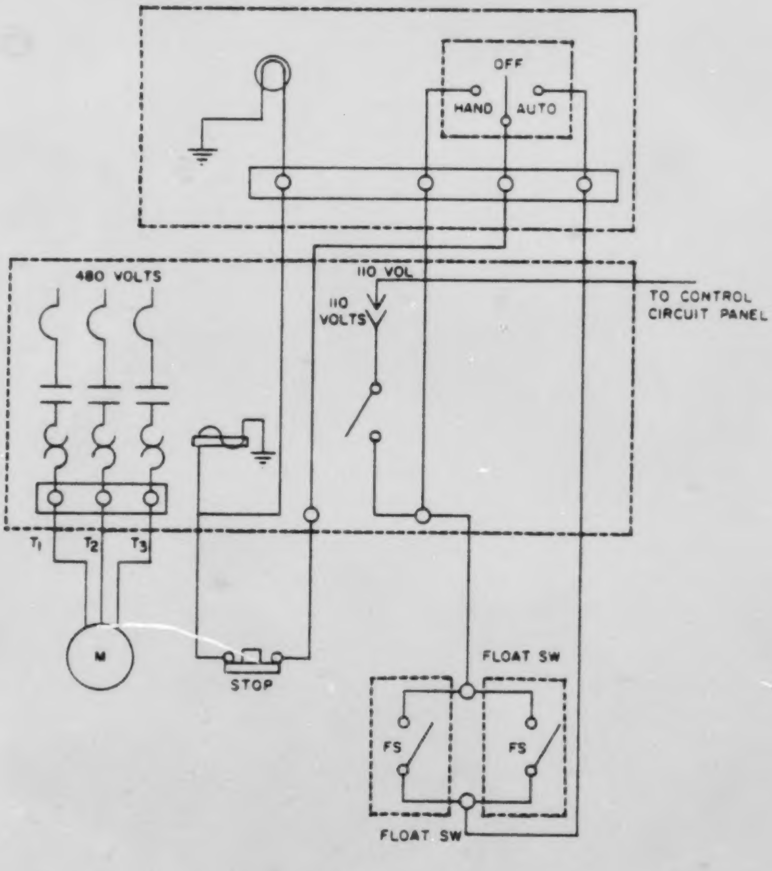

OFF
HAND
AUTO
480 VOLTS
110 VOL
110
VOLTS
TO CONTROL
CIRCUIT PANEL
T1
T2
T3
M
STOP
FLOAT SW
FS
FS
FLOAT SW

Figure 60. Characteristic Wiring Diagram Controlled by Manual and Float Switches

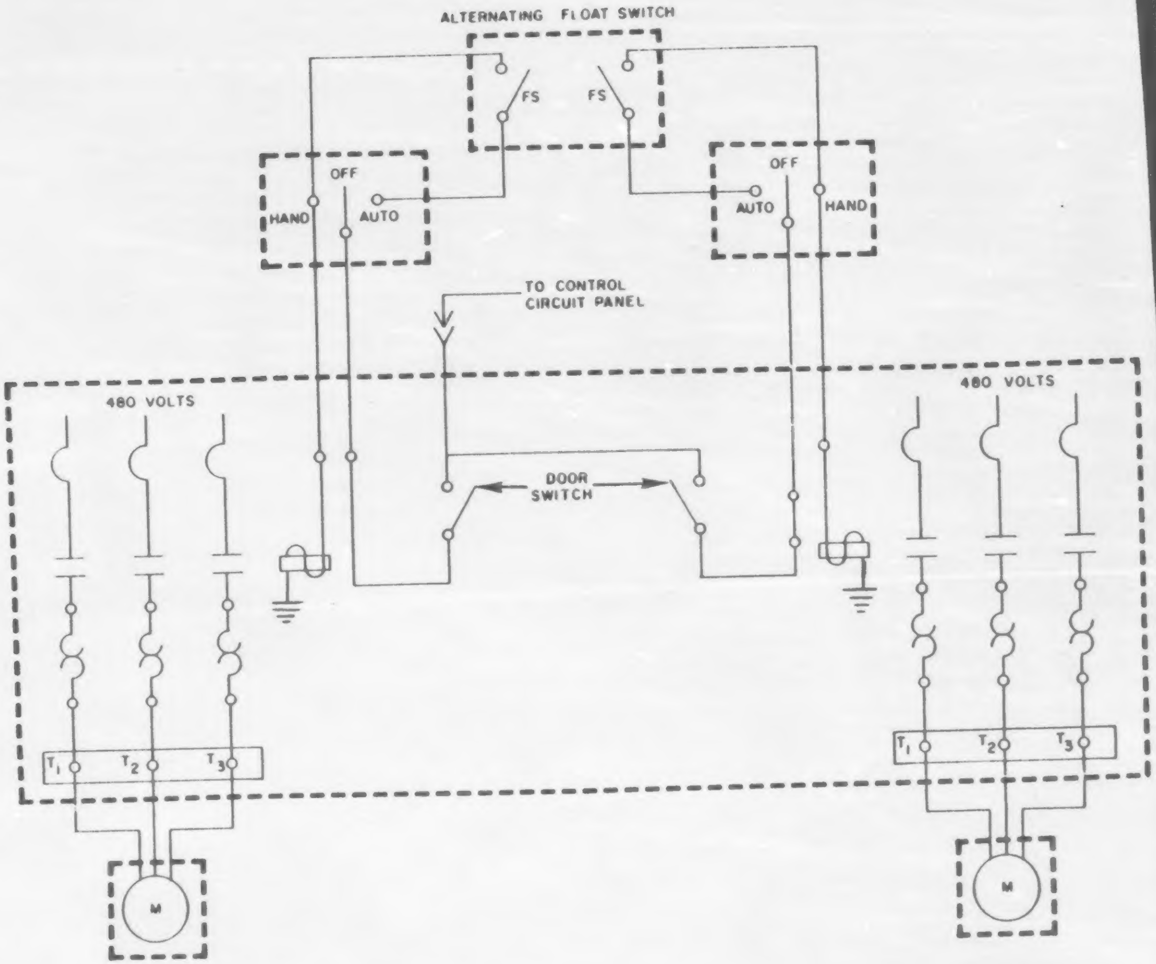

ALTERNATING FLOAT SWITCH
FS
FS
OFF
HAND
AUTO
OFF
AUTO
HAND
TO CONTROL CIRCUIT PANEL
480 VOLTS
480 VOLTS
DOOR SWITCH
T_1
T_2
T_3
T_1
T_2
T_3
M
M

Figure 61. Diagram Incorporating Manual, Float, and Microswitches for Control

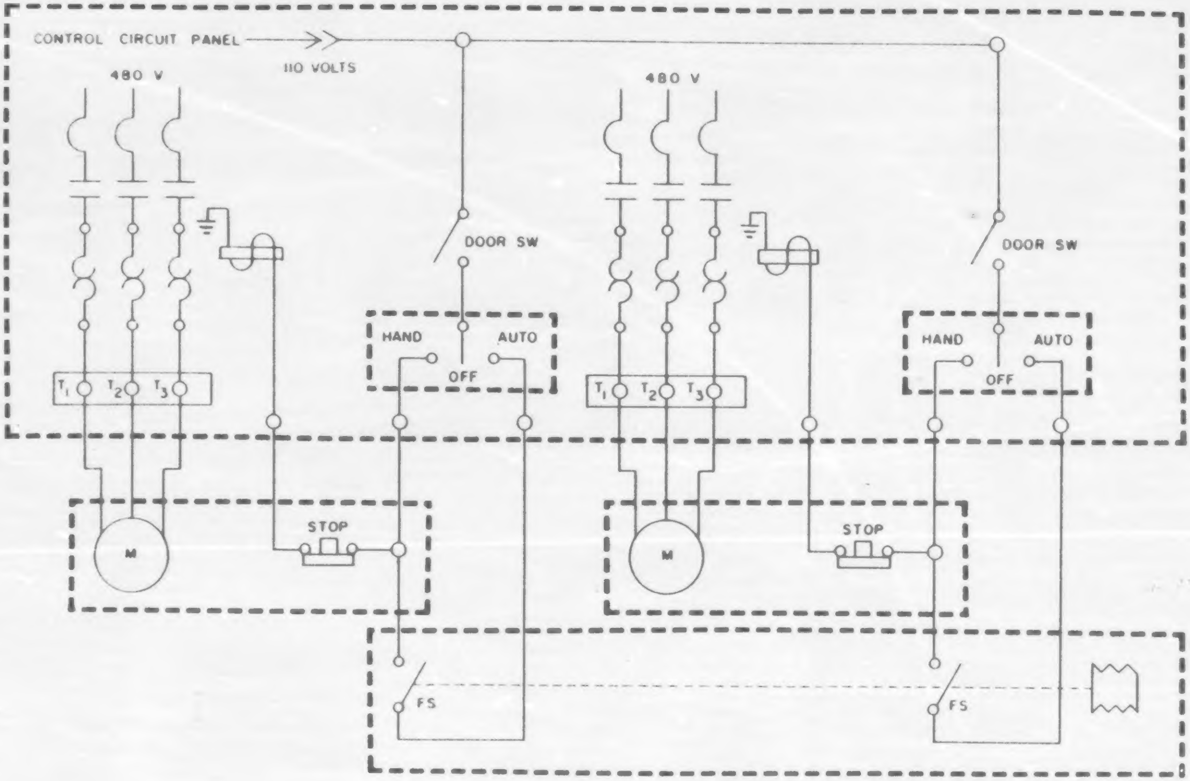

CONTROL CIRCUIT PANEL
110 VOLTS
480 V
DOOR SW
HAND
AUTO
OFF
T_1
T_2
T_3
M
STOP
FS
480 V
DOOR SW
HAND
AUTO
OFF
T_1
T_2
T_3
M
STOP
FS

Figure 62. Wiring Diagram Incorporating Manual, Pressure Pushbutton and Microswitches

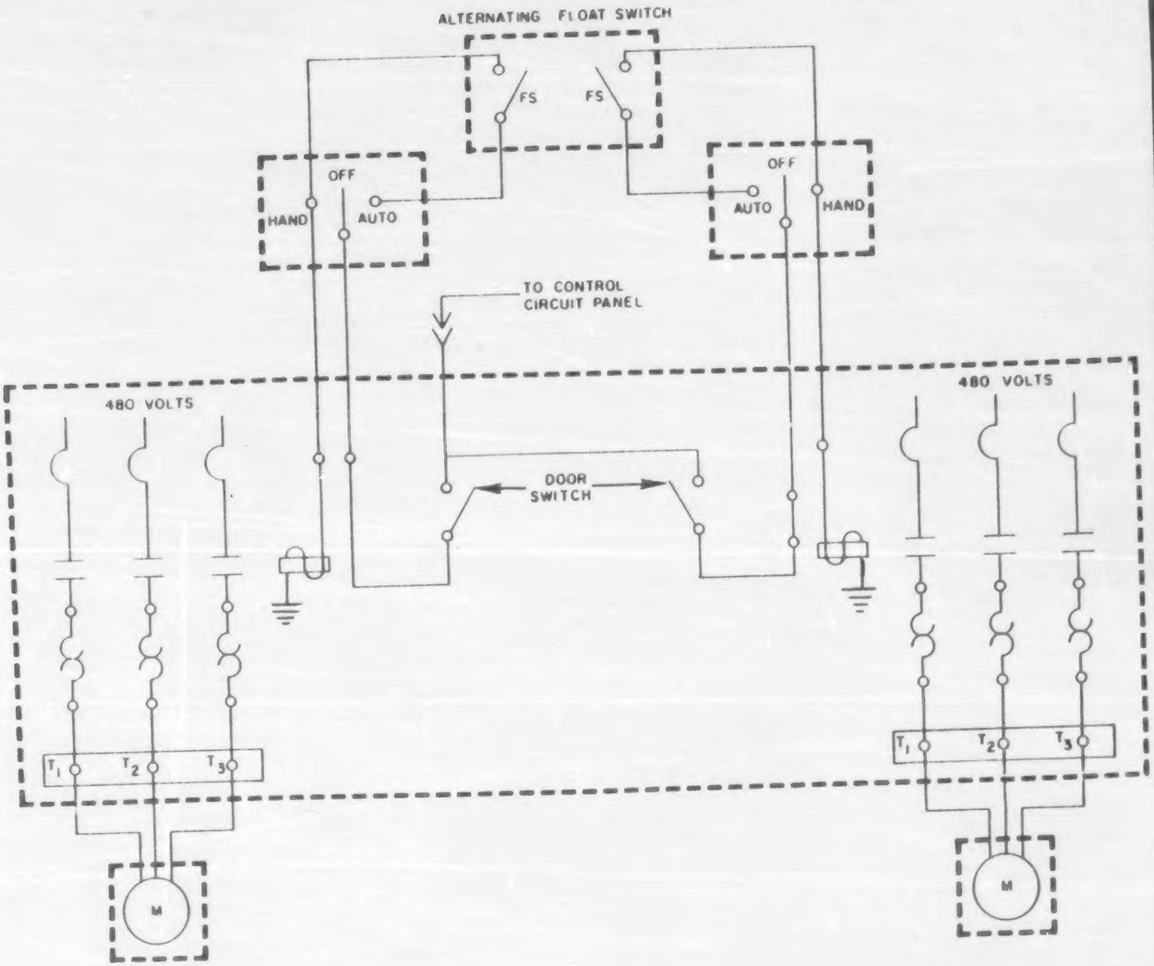

ALTERNATING FLOAT SWITCH
FS
FS
OFF
HAND
AUTO
OFF
AUTO
HAND
TO CONTROL
CIRCUIT PANEL
480 VOLTS
480 VOLTS
DOOR
SWITCH
T_1
T_2
T_3
T_1
T_2
T_3
M
M

Figure 61. Diagram Incorporating Manual, Float, and Microswitches for Control

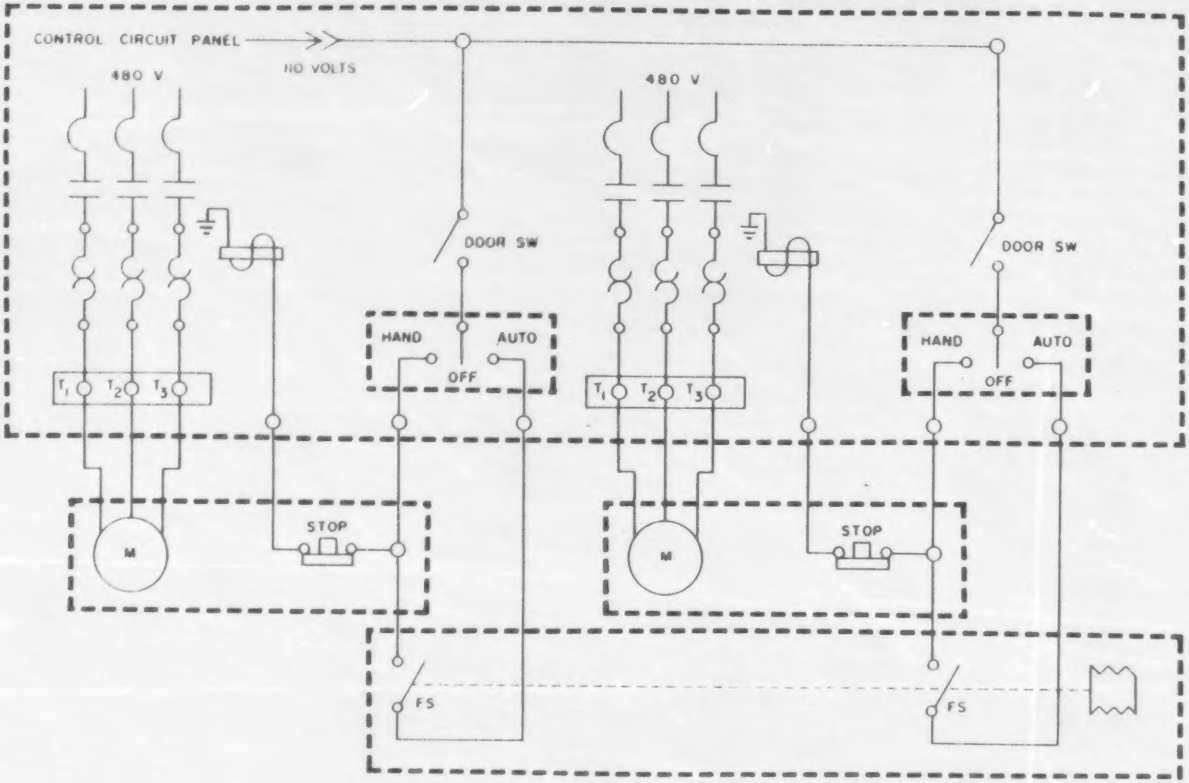

CONTROL CIRCUIT PANEL
110 VOLTS
480 V
480 V
DOOR SW
DOOR SW
HAND
AUTO
OFF
HAND
AUTO
OFF
T_1
T_2
T_3
T_1
T_2
T_3
M
M
STOP
STOP
FS
FS

Figure 62. Wiring Diagram Incorporating Manual, Pressure Pushbutton and Microswitches

SUMMARY

Motor control center provides an ideal means of centralizing motor control and related equipment. It offers grouped-control installation and operation advantages. Design flexibility--performance--safety for personnel, and equipment ease of maintenance and installation are all contained in a motor control center. The cost expense of conduit runs, pull boxes, junction boxes, and wire and cable pulling are reduced.

The major components on the face of the motor control center are control switches, pushbuttons, indicating lights, time meters, ammeters, voltmeters, metering switches, time clock, and HOA switches. The components within the motor control center are the circuit breakers, control transformers, contactors, and relays.

As an electrician, you will be responsible for the proper operation of the motor control center. You will inspect the equipment periodically and isolate malfunctions as they occur.

QUESTIONS

1. What is the primary purpose of the MCC?

2. List the components found on the face of the MCC.

3. List the major components found within the MCC.

4. What are four advantages of an MCC.

5. What is the purpose of the circuit breakers?

6. What type of connection is shown between pressure switches in figure 92 of this study guide?

Equipment and Supplies	Unit/Issue
SG 3ABR54230-1-IV-4	1/student

SECTION II

MOTOR GENERATORS

A motor generator is a motor-driven generator converting mechanical energy into electrical energy. It is designed to deliver a controlled voltage and/or frequency. A motor generator consists of a prime mover, an exciter, a generator, and a voltage regulator. The prime mover is a motor. It can be single- or three-phase and its purpose is to turn the exciter field. The exciter is a dc generator supplied with direct current through a voltage regulator. The voltage regulator is usually the magnetic amplifier or electromechanical type. The voltage regulator senses the voltage output of the generator windings. The generator winding can be connected for ac or dc operation. The windings are usually the stationary part of the generator.

Figure 63 shows an example of a motor generator set. Power is supplied to the prime mover which turns the exciter. The exciter is supplied direct current from the power winding. With current in the exciter, and the primer mover turning the armature, voltage is generated in the generator windings. The output voltage is sensed through the control winding which varies the amount of magnetic lines of flux in the iron core. The lines of flux will either aid or resist the current to the exciter field. The amount of current in the exciter will determine the output voltage.

SUMMARY

Motor generator sets consist of a prime mover (motor), an exciter (armature), windings, and a voltage regulator. The motor generator set may be used to regulate voltage and/or change the frequency.

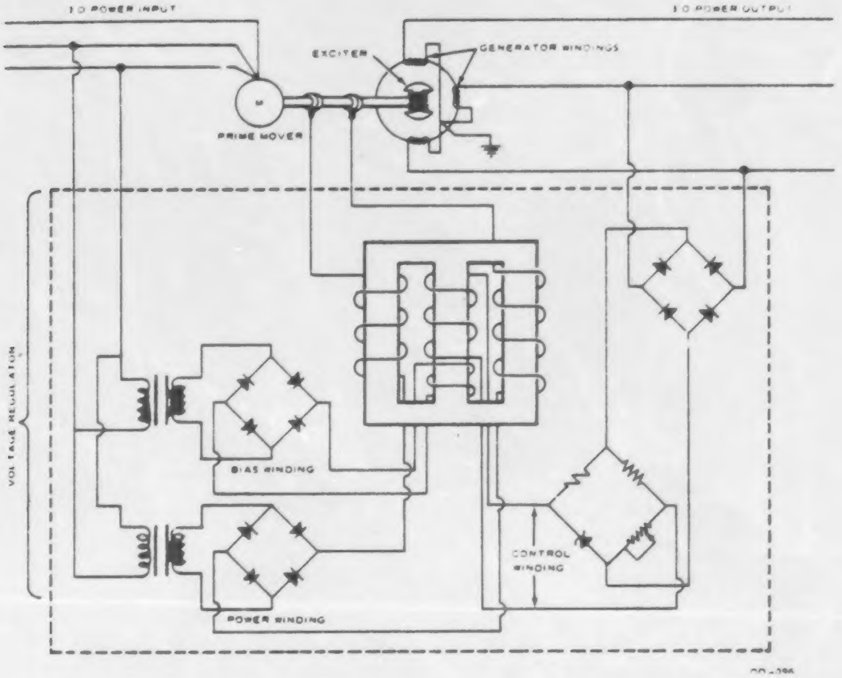

3 Ø POWER INPUT
3 Ø POWER OUTPUT
EXCITER
GENERATOR WINDINGS
M
PRIME MOVER
VOLTAGE REGULATION
BIAS WINDING
POWER WINDING
CONTROL WINDING

Figure 63. Motor Generator Set

QUESTIONS

1. What are the three factors necessary to generate a voltage?

2. The exciter is what type of generator?

3. The stationary part of a generator is usually referred to as ________________

____.

4. The rotating part of a generator is usually referred to as ________________

____.

5. What determines the amount of output voltage?

REFERENCES

AFM 85-17, Maintenance and Operation of Electric Plants and Systems.
AFR 85-19, Maintenance and Operation of Electric Power Generating Plants.

Equipment and Supplies	Unit/Issue
SG 3ABR54230-1-IV-5	1/student

WORKBOOK 3ABR54230-1-IV-1 thru 5

Department of Civil Engineering Training

ELECTRICIAN

BLOCK IV

MOTORS AND CONTROLS

July 1975

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

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IV-4	Troubleshooting Single-Phase Motor Systems	July 1975	37
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This supersedes SW 3ABR54230-1-IV-1 thru 12, April 1973
Superseded material may be used until supply is exhausted.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-IV-1
July 1975

THREE-PHASE MOTOR SYSTEMS

OBJECTIVE

When you have completed this workbook, you will be able to:

1. Identify parts of a 3Ø motor.
2. Read a motor data plate.
3. Select a 3Ø motor for various specifications.
4. Connect a 3Ø motor to operate on 440 VAC or 220 VAC.
5. Reverse the direction of rotation of a 3Ø motor.
6. Connect a 3Ø motor to power.
7. Identify motor control components.
8. Select proper overload elements.
9. Install a 3Ø motor, controller, and a start/stop station.
10. Install a 3Ø motor, controller, and two start/stop station.
11. Install a 3Ø motor, controller, and thermostat.
12. Install a 3Ø motor, reversing magnetic controller, and reversing station.

76-179

PROCEDURE

PROJECT 1

1. Figure 1 is a picture of a three-phase motor. Identify these parts by writing the name of each part in the space provided.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

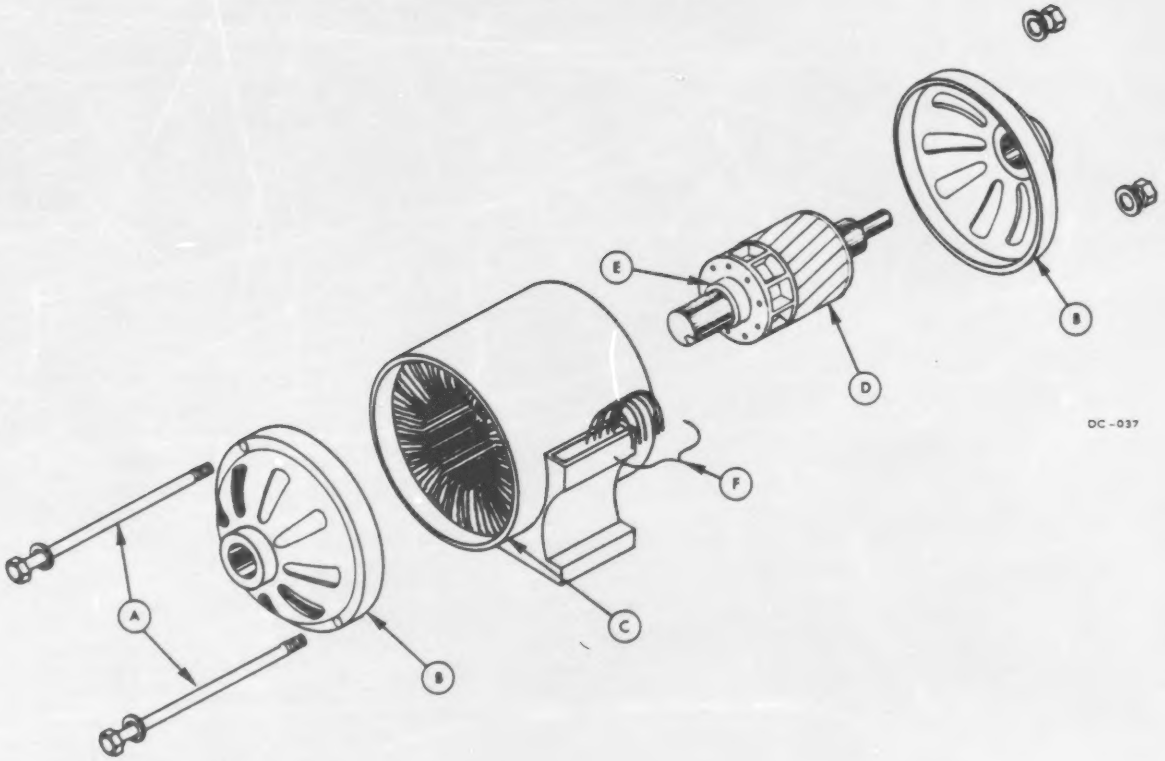


Figure 1. Three-Phase Motor

2. Match the correct terms on the left with the statements on the right by writing the number in the space provided:

a.	Rotor	______	Supports the rotor, houses the bearings and completes the frame
b.	Endbells	______	Allow the rotor to turn smoothly
c.	Stator	______	Moving part of this particular motor
d.	Bearing	______	That part of the rotor that may be a connection point for the load
e.	Shaft	______	Holds the field winding and core
f.	Field Winding	______	That which develops a rotating magnetic field
g.	Fan	______	Reduces and eliminates heat from around the inside of the motor

PROJECT 2

READING A MOTOR DATA PLATE

Using the data plate illustrated in figure 2, enter the information in the following blank spaces to adequately identify motor installation and operation data.

1. Manufacturer's Name ________________
2. Horsepower Rating ________________
3. Temperature Rise - 50 cycles ________ 60 cycles ________
4. RPM at full load - 50 cycles ________ 60 cycles ________
5. Frequency ________________
6. Number of phases ________________
7. Voltages motor will operate on ________________
8. Full load current on high voltage - 50 cycles ________________

   60 cycles ________________
9. Frame Number ________________ and design/code ____/____

General Electric - Induction Motor			
HP 2	Ph 3	Cy 50	60
Volts 208/220/440		RPM 950	1145
Frame 184		Hi Volt Amps 3.6 - 3.1	
Type K		Low Volt Amps 7.2 - 6.2	
Design B Code L		Rating 50°C - 40°C	
	SF 1.	SF 1.25	

Figure 2. Motor Data Plate

PROJECT 3

SELECTING A THREE-PHASE MOTOR TO MEET ESTABLISHED SPECIFICATIONS

Using the National Electrical Code Book, determine the specification requirements for a three-phase motor which must be capable of 24-hour daily service with a 5-horsepower load. The motor will be vertically mounted in an area where explosive gases are present. The motor will be installed to draw the least amount of full-load current. The power available is three-phase 230/460 volt service.

Place an X in the blank space opposite the material or equipment which is required to meet installation specifications.

1. DUTY

________ Continuous
________ Intermittent

2. BEARINGS

________ Sleeve
________ Roller
________ Ball

3. TYPE ENCLOSURE OF MOTOR

________ Open
________ Drip Proof
________ Totally Enclosed
________ Dust Explosionproof
________ Vapor Explosionproof

4. CONDUIT SIZE

________ 1/2 inch
________ 3/4 inch
________ 1 inch

5. FUSE SIZE

________ 30 amp
________ 15 amp
________ 25 amp
________ 10 amp

6. SIZE CLASSIFICATION

________ Fractional-Horsepower
________ Integral-Horsepower

7. VOLTAGE

________ 110 volts
________ 220 volts
________ 440 volts

8. FULL LOAD CURRENT

________ 6.1 amp
________ 7.6 amp
________ 13.2 amp
________ 15.2 amp

9. CONTROLLER ENCLOSURE TYPE

________ Open - General Purpose

________ Weather-protected

________ Moisture-protected

________ Hazardous vaporproof

________ Hazardous dustproof

10. SIZE CONDUCTORS FROM MOTOR DISCONNECT ACCORDING TO THE N. E. C.

________ 10 AWG

________ 12 AWG

________ 14 AWG

________ 18 AWG

PROJECT 4

1. Complete the schematic diagram in figure 3 by numbering the motor windings and drawing in the necessary connections and conductors for applying 440-volt power to the motor for high voltage operation.

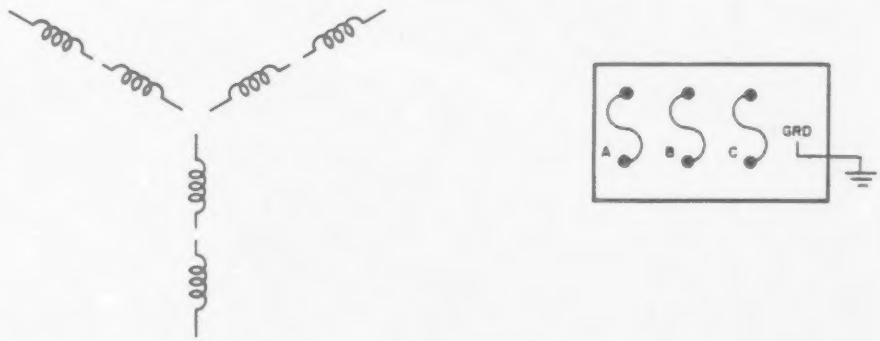


Figure 3. 440-Volt Circuit Diagram

2. Complete the schematic diagram in figure 4 by numbering the motor windings and drawing in the necessary connections and conductors for applying 220-volt power to the motor for low voltage.

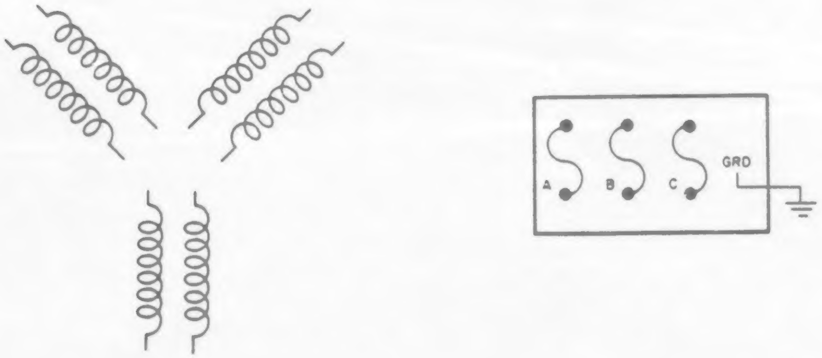


Figure 4. 220-Volt Circuit Diagram

3. Complete the schematic diagram in figure 5 by numbering the motor windings and drawing in the necessary connections and conductors for applying 440-volt power to the motor for high voltage.

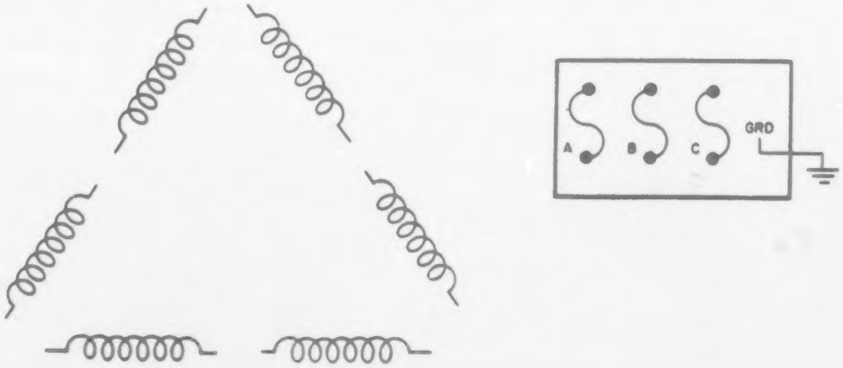


Figure 5. 440-Volt Circuit Diagram

4. Complete the schematic diagram in figure 6 by numbering the motor windings and drawing in the necessary connections and conductors for applying 220-volt power to the motor for low voltage.

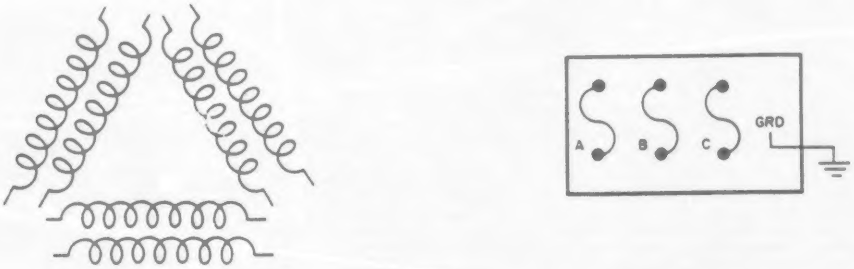


Figure 6. 220-Volt Circuit Diagram

PROJECT 5

Show connections for reversing the direction of rotation by numbering the motor windings and drawing in the necessary connections for a wye connected high voltage system on figure 7.

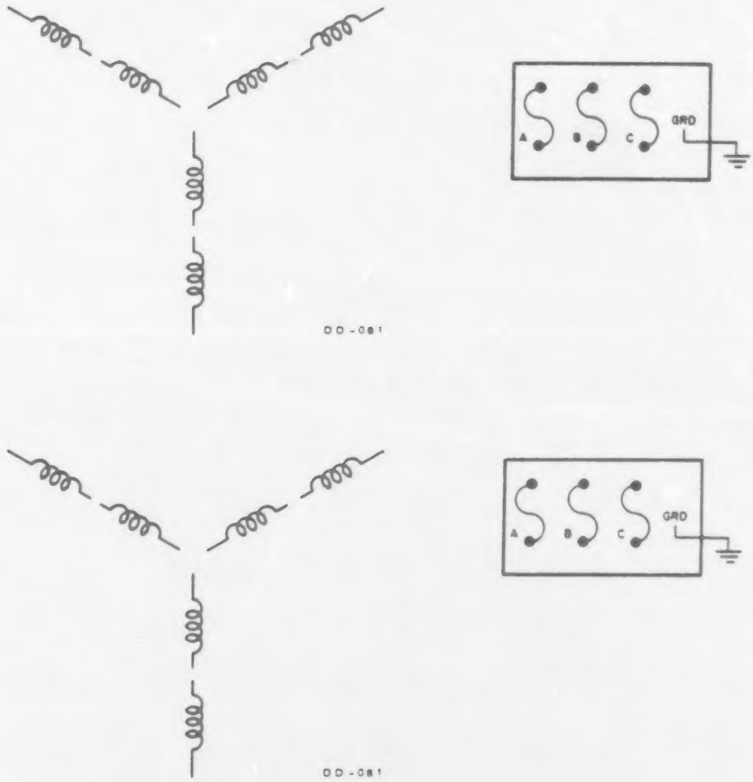


Figure 7. Reversing a Three-Phase Motor

PROJECT 6

Connect a three-phase wye motor to a 220-volt power source, using the following steps:

1. Obtain a length of 3/4" flexible conduit to reach from the 30-ampere disconnect to the motor terminal box, as shown in figure 8.

2. Run three black conductors through the flexible conduit to the motor. Permit the leads to extend an additional 6 inches inside the motor terminal box.

3. Connect the flexible conduit with the proper squeeze type connectors to the motor terminal and 30-amp disconnect box.

4. In the 30-ampere disconnect, connect the 3 leads to the bottom terminals of the fuse holders.

5. Reverse the direction of rotation of motor by interchanging two power leads to the motor.

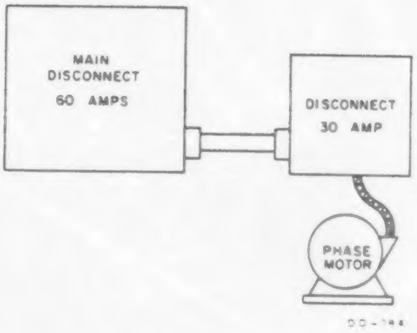


Figure 8. Connecting a Three-Phase Motor to Power

PROJECT 7

IDENTIFICATION OF MOTOR CONTROL COMPONENTS

Figure 9 shows components of the motor starter in schematic form. Identify each of the numbered components on the arrows provided.

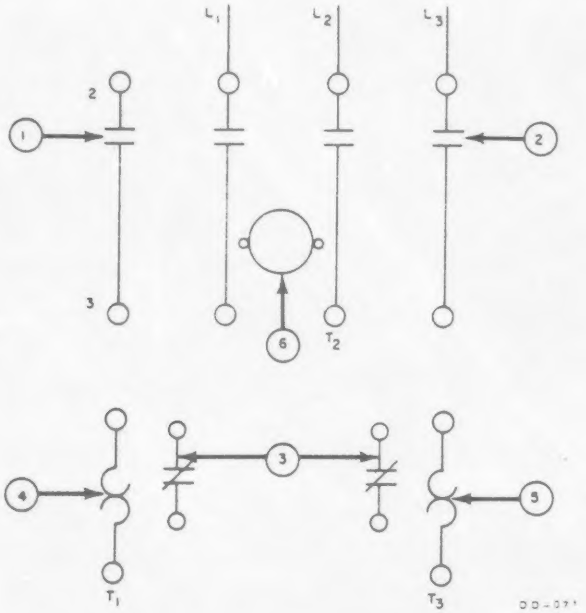


Figure 9. Three-Phase Starter Schematic Diagram

State the purpose of the following magnetic starter components:

1. Coil: ____________________

2. Main or load contacts: ____________________

3. Reset contacts: ____________________

4. Overload heater element: ____________________

5. Reset pushbutton: ____________________

PROJECT 8

SELECTING THE PROPER OVERLOAD ELEMENT

INSTRUCTIONS: To answer the questions below use the tables on figures 12, 13, and 14, and a motor data plate to determine the number of the overload element (relay, heater, or fuse) to be used with the types of motor starters listed below. Write the number of the overload element in the blank space provided.

1. Observe the motor data plate shown in figure 10; if the motor is connected to high voltage, what number overload would be used?

Square D No. ____________________

Allen Bradley No. ________________

Arrow Hart No. __________________

Century Capacitor Single Phase Motor	
Model GSA-203-CA6-5FA	
HP 1	RPM 1750
Volts 115/230	AMPS 12/6 Cy 60
Time Rating - Cont open	Temp Rise 40°C
	SF1.25

OO-035A

Figure 10. Motor Data Plate

2. Observe the motor data plate shown in figure 11. If the motor is connected to low-voltage, 60-cycle power, what number overload would be used?

Allen Bradley No. ________________

Arrow Hart No. __________________

Square D No. ____________________

Uniclosed Motor		
HP 3	Ph 3	Cy 50 - 60
Volts 208/220/440		RPM 1500 - 1800
Frame 213		Hi Volt Amps 4.7 - 4.3
Type H		Lo Volt Amps 9.4 - 8.6
Design B Code J		Rating 50° - 40°C
208 Volt Amps 9.1		

OO-035B

Figure 11. Motor Data Plate

3. Observe the data plate shown in figure 10. If the motor is connected to low voltage, what number overload would be used?

Allen Bradley No. ______________

Square D No. ______________

Arrow Hart No. ______________

4. Observe the figure 11 data plate. If the motor is connected to low voltage, 50-cycle power, what number overload would be used?

Square D No. ______________

Allen Bradley No. ______________

Arrow Hart No. ______________

5. If a motor having a data plate like the one shown in figure 11 is connected to 208-volt, 60-cycle power, what number overload would be used?

Arrow Hart No. ______________

Square D No. ______________

Allen Bradley No. ______________

Motor full load current	Relay Number	Motor full load current	Relay Number	Motor full load current	Relay Number	
0.32-0.34	B 0.44	1.97-2.23	B 2.65	10.0-10.6	B-14	
0.35-0-38	B 0.51	2.24-2.50	B 3.00	10.7-11.4	B 15.5	
0.39-0.44	B 0.57	2.51-2.81	B 3.30	11.5-12.3	B 17.5	
0.45-0.53	B 0.63	2.82-3.19	B 3.70	12.4-13.6	B 19.5	
0.54-0.58	B 0.71	3.20-3.61	B 4.15	13.7-14.6	B 22	
0.59-0.66	B 0.81	3.62-4.14	B 4.85	14.7-16.8	B 25	
0.67-0.74	B 0.92	4.15-4.40	B 5.50	16.9-18.6	B 28	
0.75-0.84	B 1.03	4.41-4.78	B 6.25	18.7-20.2	B 32	
0.85-0.97	B 1.16	4.79-5.44	B 6.90	20.3-22.8	B 36	
0.98-1.12	B 1.30	5.45-6.16	B 7.70	22.9-24.7	B 40	
1.13-1.19	B 1.45	6.17-6.86	B 8.20	24.8-27.0	B 45	
1.20-1.34	B 1.67	6.87-7.64	B 9.10			
1.35-1.54	B 1.88	7.65-8.41	B10.2			
1.55-1.78	B 2.10	8.42-8.77	B11.5			
1.79-1.96	B 2.40	8.78-9.9	B12.8			

CA-021B

Figure 12. Square D Table

Heater Type No.	Full load Amps	Heater Type No.	Full load Amps	Heater Type No.	Full load Amps	Heater Type No.	Full load Amps
N 2	0.48	N 11	1.45	N 20	3.47	N 29	8.35
N 3	0.59	N 12	1.62	N 21	3.88	N 30	9.13
N 4	0.74	N 13	1.77	N 22	4.29	N 31	10.5
N 5	0.81	N 14	1.93	N 23	4.80	N 32	11.3
N 6	0.89	N 15	2.16	N 24	5.22	N 33	12.6
N 7	0.97	N 16	2.41	N 25	5.76	N 34	14.3
N 8	1.11	N 17	2.68	N 26	6.41		
N 9	1.22	N 18	2.93	N 27	7,02		
N 10	1.31	N 19	3.18	N 28	7.74		

CA-021A

Figure 13. Allen Bradley Table

Heater Cat Nr	Trip Amps	Full Load Motor Amps Min. Max.	Max. Fuse Size	Heater Cat Nr	Trip Amps	Full Load Motor Amps Min. Max.	Max. Fuse Size
42013	7.2	5.76 - 6.53	20	42022	22.4	17.9 - 19.4	80
42014	8.4	6.72 - 7.59	25	42225	25.0	20.0 - 21.8	100
42015	9.6	7.7 - 8.4	35	42226	28.0	22.4 - 24.4	100
42016	10.9	8.7 - 9.5	35	42227	32.6	26.0 - 28.3	125
42017	12.6	10.1 - 11.0	40	42228	36.3	29.0 - 31.6	125
42018	13.7	11.0 - 11.5	45	42229	42.0	33.5 - 36.5	150
42019	14.5	11.6 - 12.6	50	42230	48.0	38.4 - 41.5	150
42020	15.8	12.6 - 13.7	50	42231	52.0	41.6 - 45.2	175
42021	18.3	14.6 - 15.9	60	42232	57.0	45.5 - 49.0	200
42224	20.0	16.0 - 17.6	70	42233	60.5	49.0 - 52.5	200

CA-020

Figure 14. Arrow Hart Table

PROJECT 9

CONNECTING THREE-PHASE CONTROLLERS

1. Complete the diagrams in figures 15, 16, and 17.

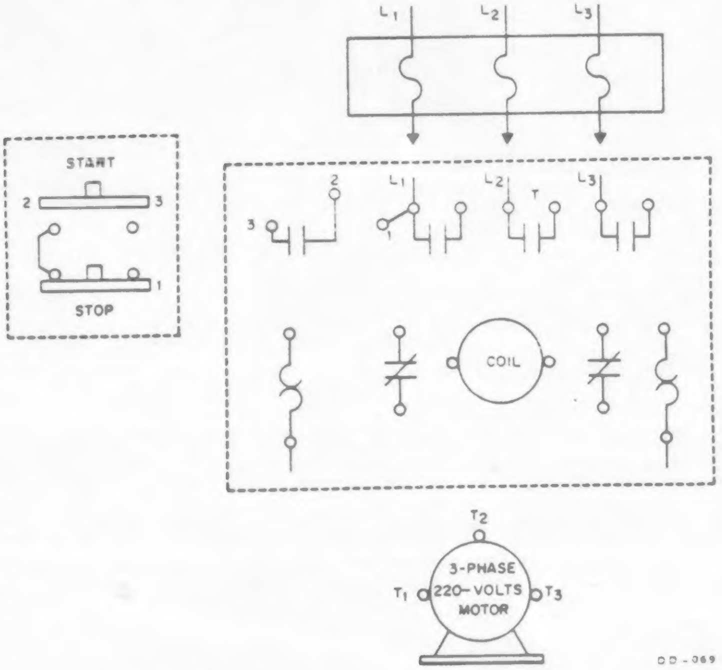

L1
L2
L3
START
2
3
1
STOP
2
3
L1
L2
T
L3
1
COIL
T2
T1
T3
3-PHASE
220-VOLTS
MOTOR
DD-069

Figure 15. Connecting a Three-Phase Square-D Magnetic Starter For Low Voltage

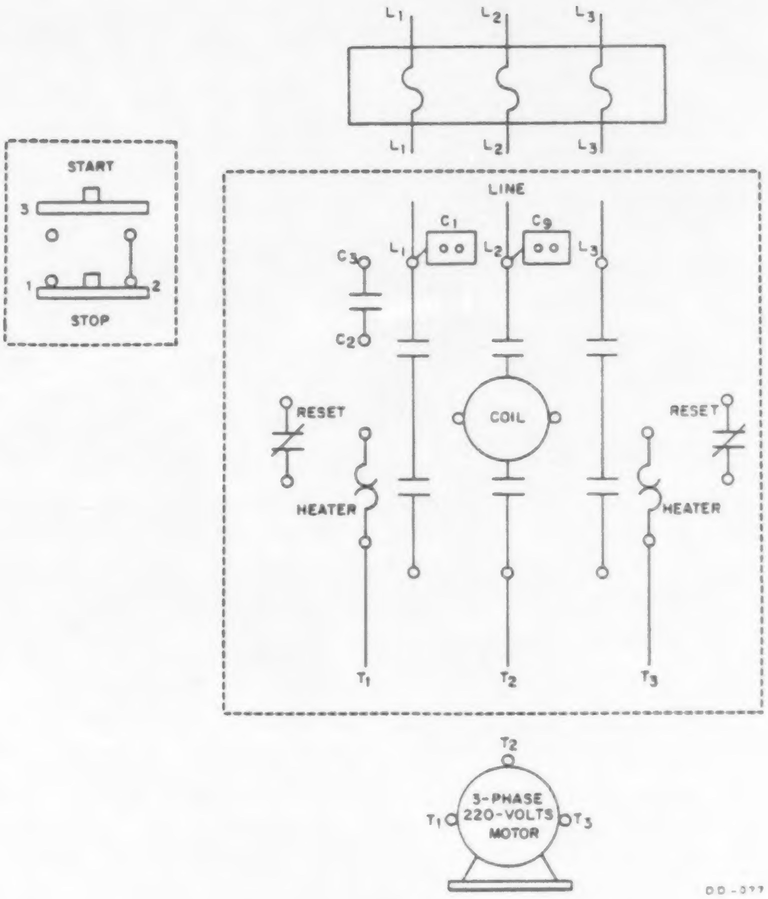

L1
L2
L3
L1
L2
L3
START
3
1
2
STOP
LINE
C1
C9
L1
L2
L3
C3
C2
RESET
COIL
RESET
HEATER
HEATER
T1
T2
T3
T2
T1
3-PHASE
220-VOLTS
MOTOR
T3
DD-077

Figure 16. Connecting a Three-Phase Arrow-Hart Magnetic Starter For Low Voltage

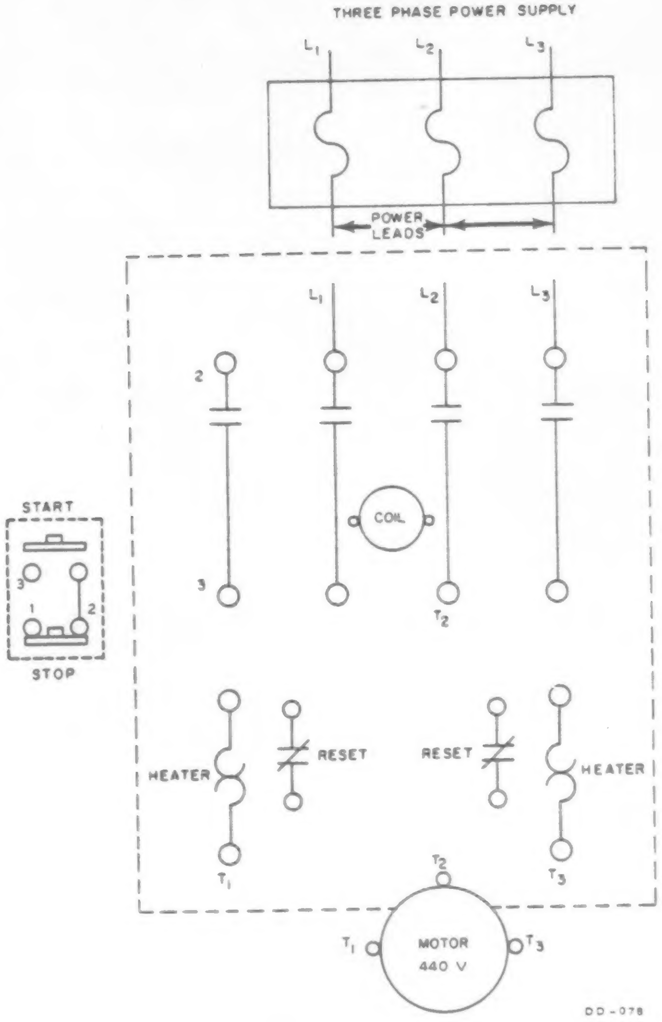

THREE PHASE POWER SUPPLY
L1
L2
L3
POWER LEADS
L1
L2
L3
2
3
COIL
T2
START
3
1
2
STOP
HEATER
RESET
RESET
HEATER
T1
T2
T3
T1
MOTOR
440 V
T3
DD-078

Figure 17. Connecting a Three-Phase Allen-Bradley Starter For High Voltage

PROJECT 10

Step 1. Using one of the diagrams you completed in project 9, install and connect a three-phase motor controlled by a magnetic starter and one start-stop station.

Step 2. Have the instructor check your work. (CAUTION--Do not turn the power ON.)

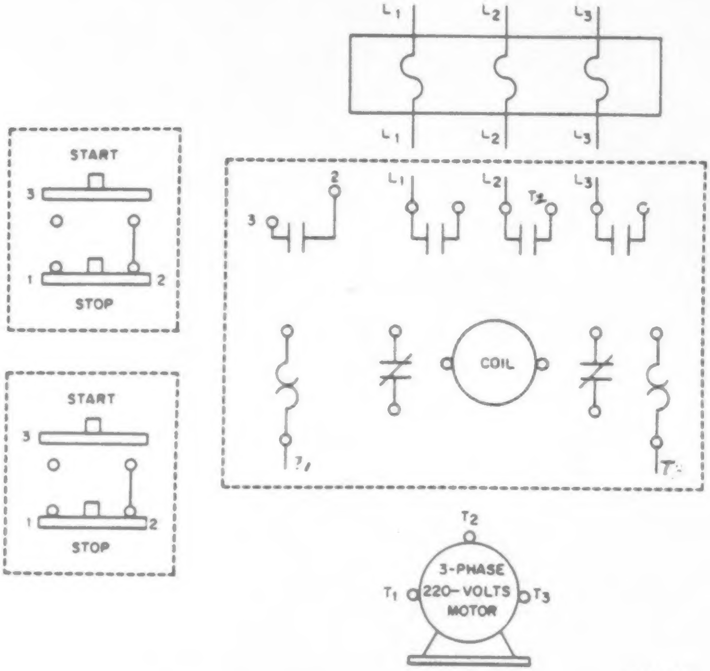
Step 3. Operate the motor to insure correct operation.

Step 4. Have the instructor check your work.

(Instructor's Signature)

PROJECT 11

Step 1. Complete the following diagram, Figure 18.


L1
L2
L3
START
3
1
2
STOP
START
3
1
2
STOP
2
3
L1
L2
T2
L3
COIL
T1
T3
T2
T1
3-PHASE
220-VOLTS
MOTOR
T3

DD-098

Figure 18. Connecting a Three-Phase Motor System Using Two Start-Stop Stations

Step 2. Using the diagram you have just completed in step 1, add a start-stop station to the motor control system you installed in project 3.

Step 3. Have the instructor check your work. (CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

(Instructor's Signature)

Step 6. Remove the two start-stop stations. Leave the magnetic starter and motor connected.

CAUTION: Make sure the power is turned OFF before attempting to complete this step.

PROJECT 12

Step 1. Complete the following diagram, figure 19.

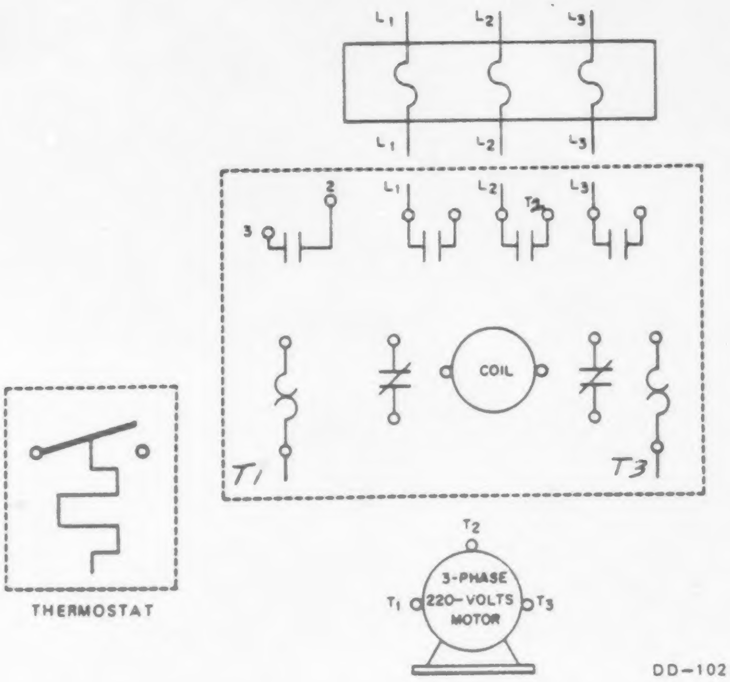

L1
L2
L3
L1
L2
L3
2
3
L1
L2
T2
L3
COIL
T1
T3
THERMOSTAT
T2
T1
3-PHASE
220-VOLTS
MOTOR
T3
DD-102

Figure 19. Connecting a Three-Phase Motor System Using a Thermostat

Step 2. Using the diagram you have just completed in step 1, install a thermostat to control the three-phase motor system on your trainer.

Step 3. Have the instructor check your work. (CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

____
Instructor's Signature

Step 6: Remove all installed equipment (except the safety switch) from your trainer.

PROJECT 13

Step 1: Complete the following diagram, figure 20.

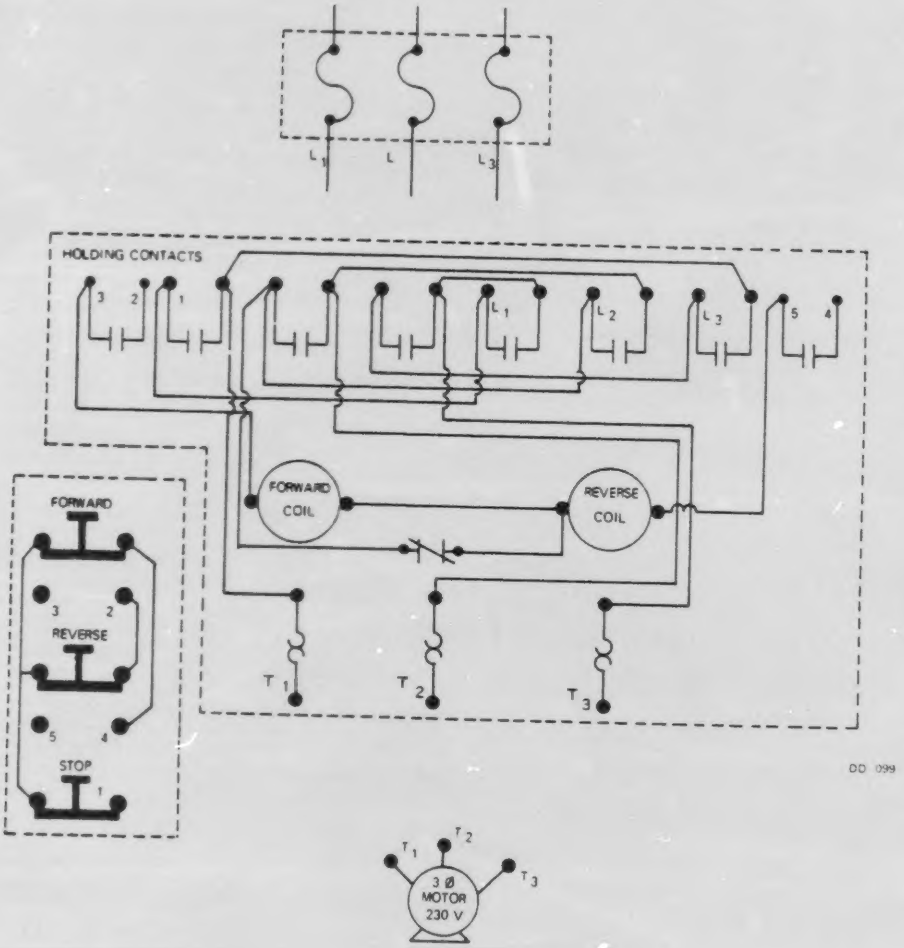

L1
L
L3
HOLDING CONTACTS
3
2
1
L1
L2
L3
5
4
FORWARD COIL
REVERSE COIL
T1
T2
T3
FORWARD
3
2
REVERSE
5
4
STOP
1
DD 099
T1
T2
T3
3 Ø MOTOR 230 V

Figure 20. Connecting a Forward-Reverse Controller

Step 2. Using the diagram you have just completed in step 1, install a three-phase forward-reverse control system to control the three-phase motor on your trainer.

Step 3. Have the instructor check your work. CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

(Instructor's Signature)

Step 6. Remove all installed equipment from your trainer and store it in the proper location in the trainer.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-IV-2
July 1975

TROUBLESHOOTING THREE-PHASE MOTOR SYSTEMS

OBJECTIVES

When you have completed this workbook, you will be able to:

1. Perform an operational check on a motor control system.
2. Troubleshoot a motor control system for opens, shorts, and grounds.
3. Repair electrical troubles.

PROJECT 1

INSTRUCTIONS. Using diagram provided in figure 21, select the observable symptom which will be the result for each trouble. Consider each trouble to be the only one in the system.

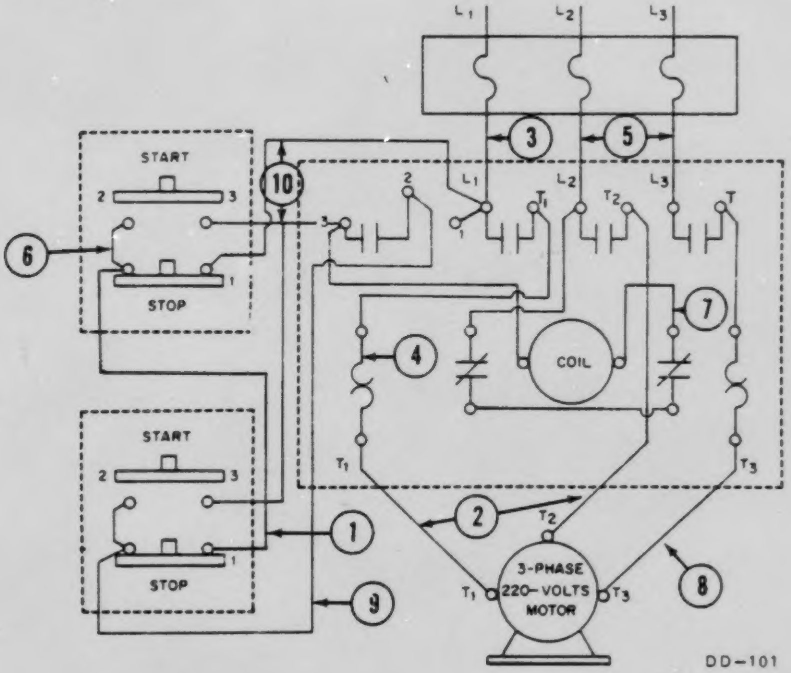

L1
L2
L3
START
2
3
STOP
1
⑥
⑩
③
⑤
T1
T2
T
④
COIL
⑦
START
2
3
STOP
1
①
⑨
②
⑧
T1
T2
T3
3-PHASE
220-VOLTS
MOTOR
DD-101

Figure 21. Three-Phase Motor System

TROUBLE POINT	TROUBLES	OBSERVED SYMPTOM
1.	Open	________
2.	Short	________
3.	Open	________
4.	Open	________
5.	Short	________
6.	Open	________
7.	Open	________
8.	Open	________
9.	Open	________
10.	Short	________

SYMPTOM

a. Motor single phases.
b. Blown fuse in panel.
c. Reset trips.
d. Motor will not start.
e. Motor will not stop with either station.
f. Motor starts, but stops when start button is released.
g. Motor will start with only one station.

PROJECT 2

Step 1. Troubles have been created in your trainer. You are to locate and correct these troubles.

Step 2. Have the instructor observe while you operate the motor system to insure all troubles have been corrected.

Step 3. Use an ammeter and check the current draw of the motor. The meter reading is ____________ amps. Compare this reading with the full load current from the motor data plate to insure the motor is drawing the proper amount of current.

Step 4. With the power turned OFF, disconnect the motor windings. With a megohmmeter, check the resistance of each set of windings.

Step 5. Have the instructor check your work.

____
(Instructor's Signature)

Step 6. Remove all installed items from the trainer and return them to their proper location. Clean and straighten trainer. Return all handtools to the trainer and have the instructor check your trainer before locking it.

____
(Instructor's Signature)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-IV-3
July 1975

SINGLE-PHASE MOTOR SYSTEMS

OBJECTIVES

When you have completed this workbook, you will be able to:

1. Identify parts of a 1φ motor.

2. Identify electrical schematics of single 1φ motors.

3. Complete electrical schematics for 120 VAC or 240 VAC hookups for a 1φ induction motor.

4. Connect a 1φ induction motor to power.

5. Connect a 1φ motor controlled by a drum control.

6. Install a 1φ motor, magnetic controller and a start/stop station.

7. Install a 1φ motor, magnetic controller and two start/stop stations.

8. Install a 1φ motor, magnetic controller and a thermostat.

9. Install a 1φ motor, magnetic controller, thermostat, and HOA switch.

PROJECT 1

The illustrations in figure 22 are the major parts of a single-phase motor. In the blank space provided, write the name of the appropriate component.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

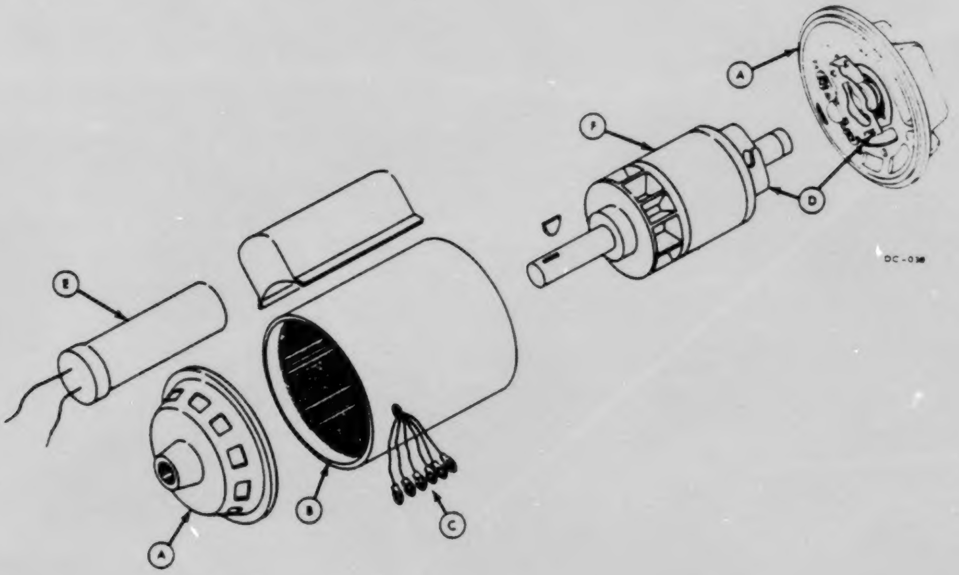


Figure 22. Major Parts of a Single-Phase Motor

PROJECT 2

1. Figures 23 and 24 are schematic drawings of two types of single-phase motors.

2. Write the name of each major component where a letter appears. In the spaces provided under each drawing, correctly identify the type of motor shown.

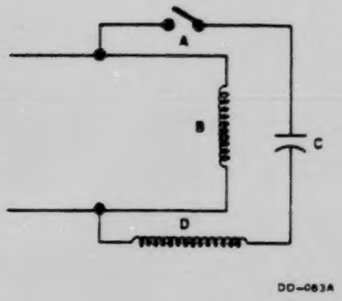


Figure 23

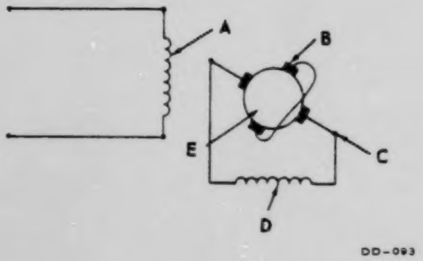


Figure 24

3. Figure 23 is the schematic of a ______________________ motor.

4. Figure is the schematic of a ______________________ motor.

5. Major components of figure 23 are:

a. ______________________

b. ______________________

c. ______________________

d. ______________________

6. Major components of figure 24 are:

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

PROJECT 3

Complete the diagram in figure 25 by numbering the motor windings and drawing in the necessary connections for 220-volt operation.

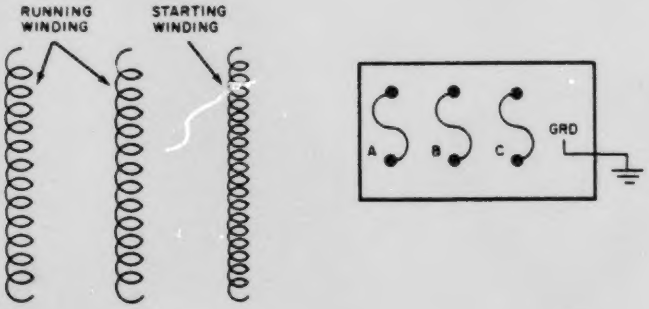

RUNNING WINDING
STARTING WINDING
A
B
C
GRD

Figure 25

Complete the diagram in figure 26 by numbering the motor windings and drawing in the necessary connections for 110-volt operation.

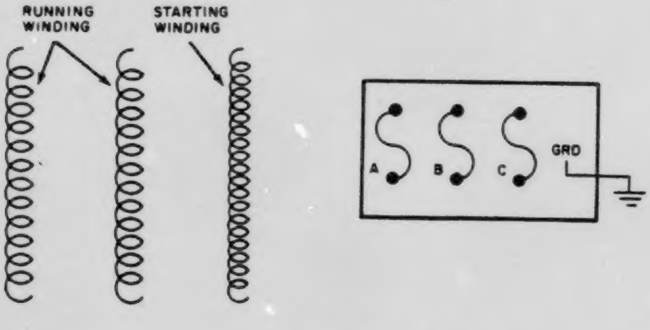

RUNNING WINDING
STARTING WINDING
A
B
C
GRD

Figure 26. Schematic of Single-Phase Motor Windings

Reverse direction of rotation of this motor compared to the motor in figure 27. Connect for low voltage.

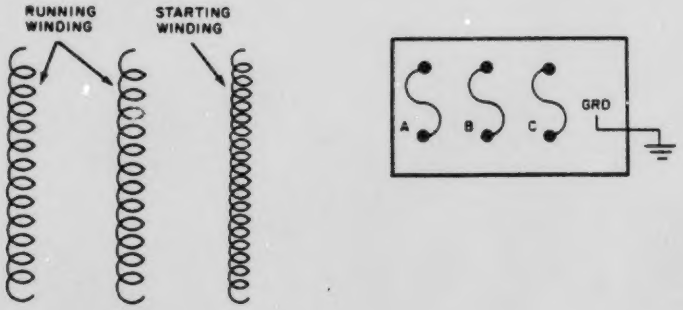

RUNNING WINDING
STARTING WINDING
A
B
C
GRD

Figure 27. Single-Phase Motor Windings

PROJECT 4
CONNECTING A SINGLE-PHASE MOTOR TO POWER

1. Obtain a piece of 3/4-inch flexible conduit long enough to reach from a 30-ampere disconnect to the motor terminal box as shown in figure 28.

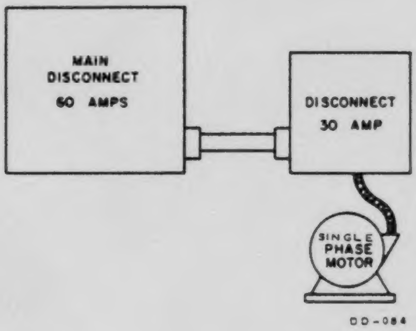

MAIN DISCONNECT 60 AMPS
DISCONNECT 30 AMP
SINGLE PHASE MOTOR
OD-084

Figure 28. Connecting a Single-Phase Motor to Power

2. Run one black and one white conductor through the flexible conduit to the motor. Permit the leads to extend in the motor terminal box about 6 inches.

3. Connect the flexible conduit with the proper type connector to the motor terminal and 30-amp disconnect box.

4. In the 30-ampere disconnect, connect the white conductor to the neutral bus bar and the black conductor to the bottom terminal of a fuse holder.

5. In the motor terminal box, connect the motor leads for low voltage. Refer to the diagram shown in figure 27 for low-voltage connections.

6. In the motor terminal box, connect the motor leads for low voltage.

PROJECT 5

Step 1. Complete the diagram pictured in figure 29. Motor will be connected for high voltage.

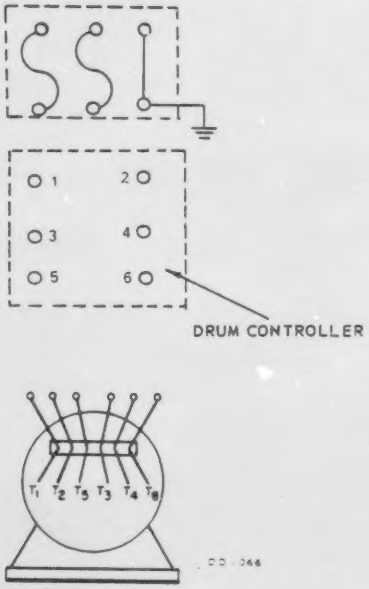


Figure 29. Single-Phase Motor Controlled by a Drum Controller

Step 2. Using the diagram you have just completed in figure 29, connect a single-phase motor controlled by a drum controller.

Step 3. Have the instructor check your work. (CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

____
(Instructor's Signature)

Step 6. Remove the drum controlled and return to proper location.

PROJECT 6

Step 1. Complete the following diagram in figure 30. Motor will operate on low voltage.

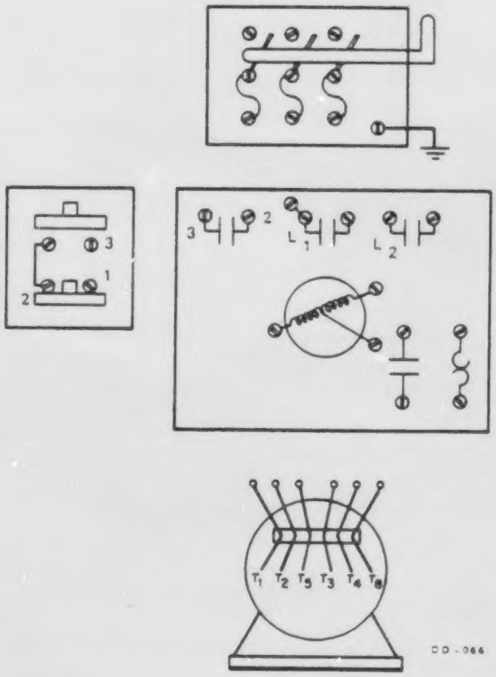


Figure 30. Connecting a Single-Phase Starter for Low Voltage

Step 2. Using the diagram you have just completed in figure 30, connect a single-phase motor controlled by a magnetic starter and one start-stop station.

Step 3. Have the instructor check your work. (CAUTION· Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

(Instructor's Signature

PROJECT 7

Step 1. Complete the following diagram in figure 31. The motor will be connected for high voltage.

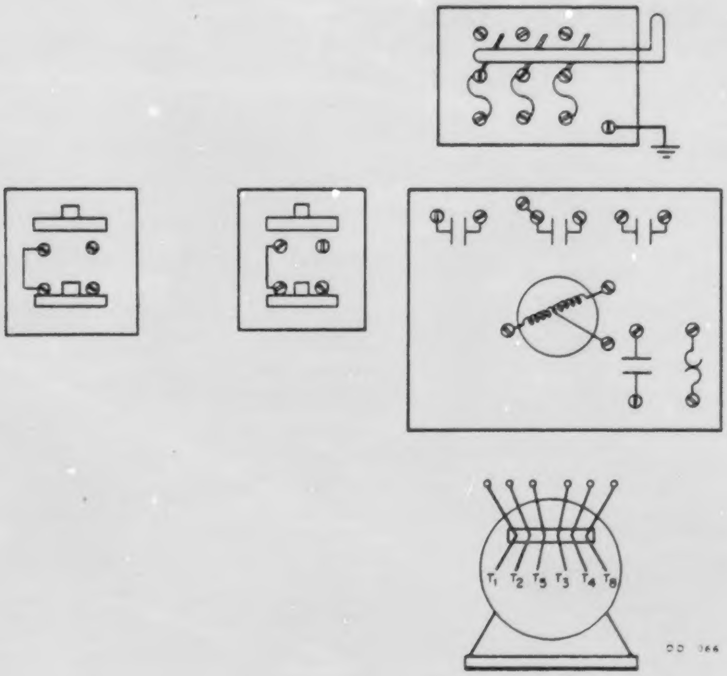


Figure 31. Connecting a Single-Phase Starter with Two Start-Stop Stations

Step 2. Using the diagram you have just completed in figure 31, add a start-stop station to the control system now installed on your trainer.

Step 3. Have the instructor check your work. (CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

____

(Instructor's Signature)

Step 6. Remove the two start-stop stations and return to proper location. Leave the magnetic starter installed.

PROJECT 8

Step 1. Complete the following diagram in figure 32.

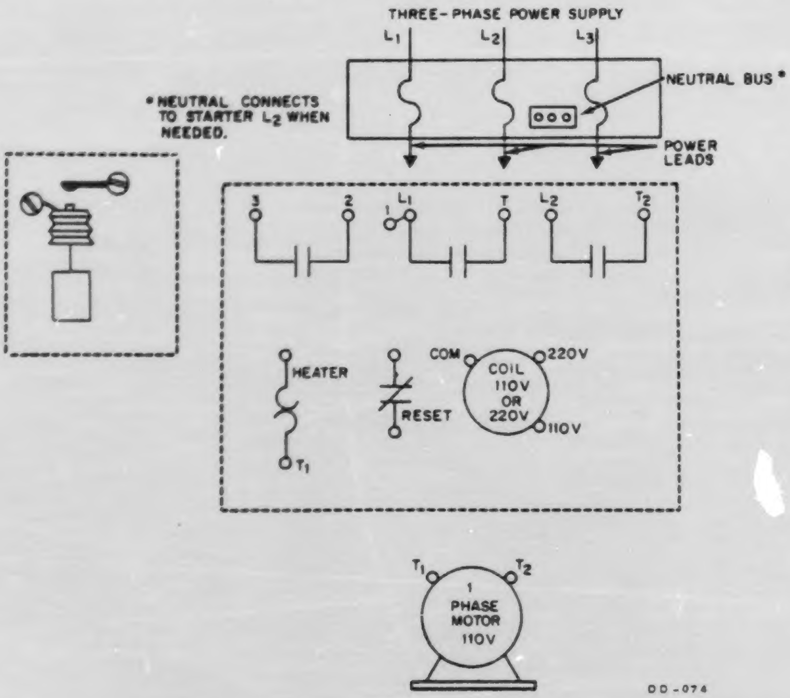

THREE-PHASE POWER SUPPLY
L_1
L_2
L_3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L_2 WHEN NEEDED.
POWER LEADS
3
2
1
L_1
T
L_2
T_2
HEATER
T_1
RESET
COM
220V
COIL 110V OR 220V
110V
T_1
T_2
1 PHASE MOTOR 110V
DD-074

Figure 32. Connecting a Single-Phase Starter with a Thermostat

Step 2. Using the diagram you have just completed in figure 32, connect a thermostat to control the magnetic starter now installed on your trainer.

Step 3. Have the instructor check your work. (CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

____
(Instructor's Signature)

PROJECT 9

Step 1. Complete the following diagram in figure 33.

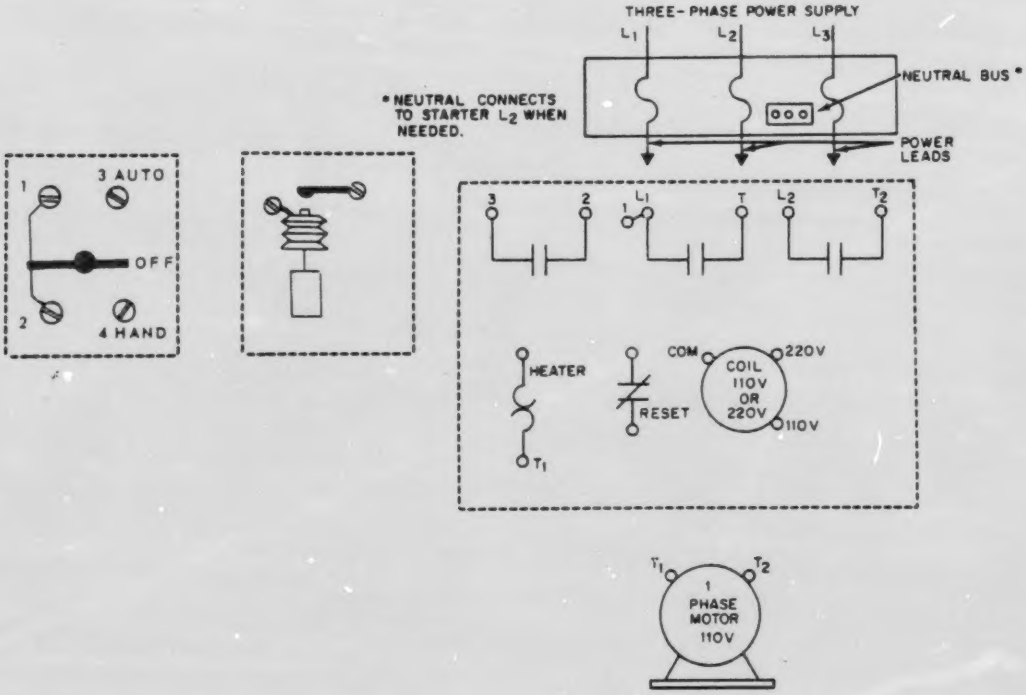

THREE-PHASE POWER SUPPLY
L_1
L_2
L_3
NEUTRAL BUS *
* NEUTRAL CONNECTS TO STARTER L_2 WHEN NEEDED.
POWER LEADS
1
3 AUTO
OFF
2
4 HAND
3
2
1
L_1
T
L_2
T_2
HEATER
T_1
RESET
COM
220V
COIL 110V OR 220V
110V
T_1
T_2
1 PHASE MOTOR 110V

Figure 33. Connecting a Single-Phase Starter with a Thermostat and a HOA Switch

Step 2. Using the diagram you have just completed, figure 33, add a HOA switch to the control system now installed on your trainer.

Step 3. Have the instructor check your work. (CAUTION: Do not turn the power ON.)

Step 4. Operate the motor to insure correct operation.

Step 5. Have the instructor check your work.

(Instructor's Signature)

NOTE: Do not remove any of this system from the trainer after you have completed this project.

Department of Civil Engineer Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-IV-4
July 1975

TROUBLESHOOTING SINGLE-PHASE MOTOR SYSTEMS

OBJECTIVES

When you have completed this workbook, you will be able to:

1. Perform an operational check on a motor control system.
2. Troubleshoot a motor control system for opens, shorts, and grounds.
3. Repair electrical troubles.

PROJECT 1

INSTRUCTIONS TO STUDENT: Using the diagram provided in figure 34, select the observable symptom which will be the result for each trouble. Consider each trouble to be the only one in the system.

TROUBLE POINT	TROUBLES	OBSERVED SYMPTOM
1.	Open	________
2.	Short	________
3.	Open	________
4.	Short	________
5.	Short	________
6.	Open	________
7.	Blown Fuse	________
8.	Open	________
9.	Open	________
10.	Open	________

SYMPTOM

a. Motor will not start.

b. Motor will not run unless contacts are held closed.

c. Motor will not stop using stop button.

d. Motor starts without pushing start button.

e. Motor runs as long as start button is held in. Stops when released.

f. Contacts close but motor does not run.

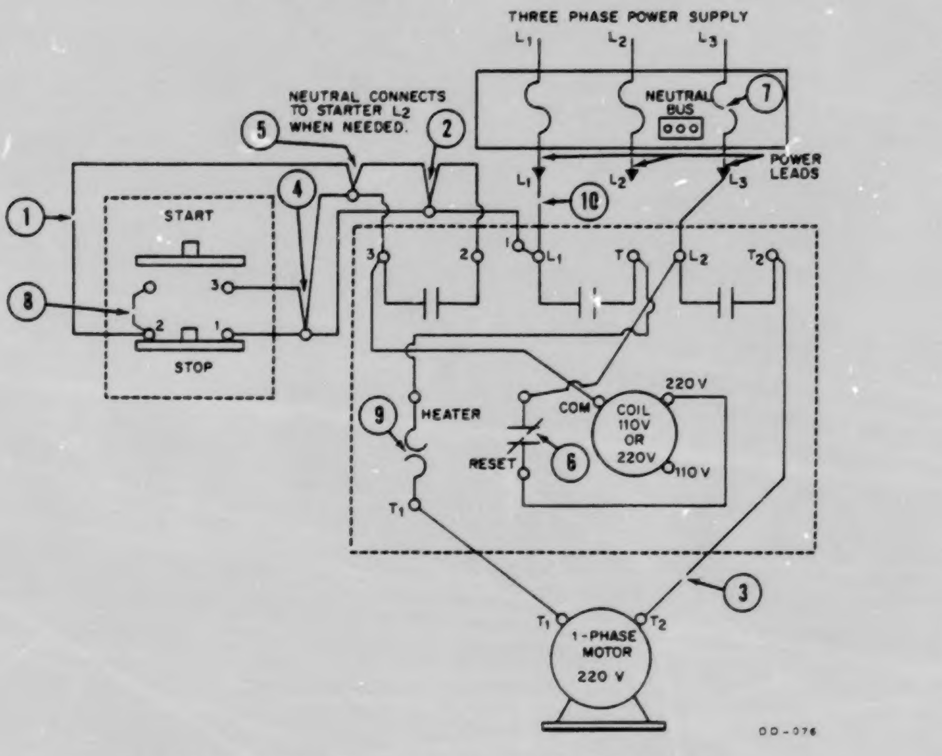

THREE PHASE POWER SUPPLY
L1
L2
L3
NEUTRAL BUS
7
POWER LEADS
NEUTRAL CONNECTS TO STARTER L2 WHEN NEEDED.
5
2
1
4
START
3
8
2
1
STOP
10
L1
L2
L3
1
L1
T
L2
T2
3
2
HEATER
9
COM
COIL 110V OR 220V
220V
110V
RESET
6
T1
3
T1
T2
1-PHASE MOTOR 220 V
OD-076

Figure 34. Single-Phase Square D Magnetic Starter

PROJECT 2

Step 1. Troubles have been created in your trainer. You are to locate and correct these troubles.

Step 2. Have the instructor observe while you operate the motor system to insure all troubles have been corrected.

Step 3. Use an ammeter and check the current draw of the motor. The meter reading is ____________ amps. Compare this reading with the full load current from the motor data plate to insure the motor is drawing the proper amount of current.

Step 4. With the power turned OFF, disconnect the motor windings. With a megohmmeter, check the resistance of each set of run windings.

Step 5. Have the instructor check your work.

____
(Instructor's Signature)

Step 6. Remove all installed items from the trainer and return them to their proper location. Clean and straighten trainer. Return all handtools to the trainer and have the instructor check your trainer before locking it.

____
(Instructor's Signature)

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-IV-5
July 1975

MOTOR GENERATORS, CONTROL PANELS, AND CIRCUIT BREAKERS

OBJECTIVES

When you have completed this workbook, you will be able to:

1. Identify the major components of a motor control center.
2. List the major components of a motor control center.
3. Identify the major parts of a motor generator set.

PROJECT 1

INSTRUCTIONS: Identify each of the numbered components shown in the motor control center schematic, figure 35, and write the nomenclature below:

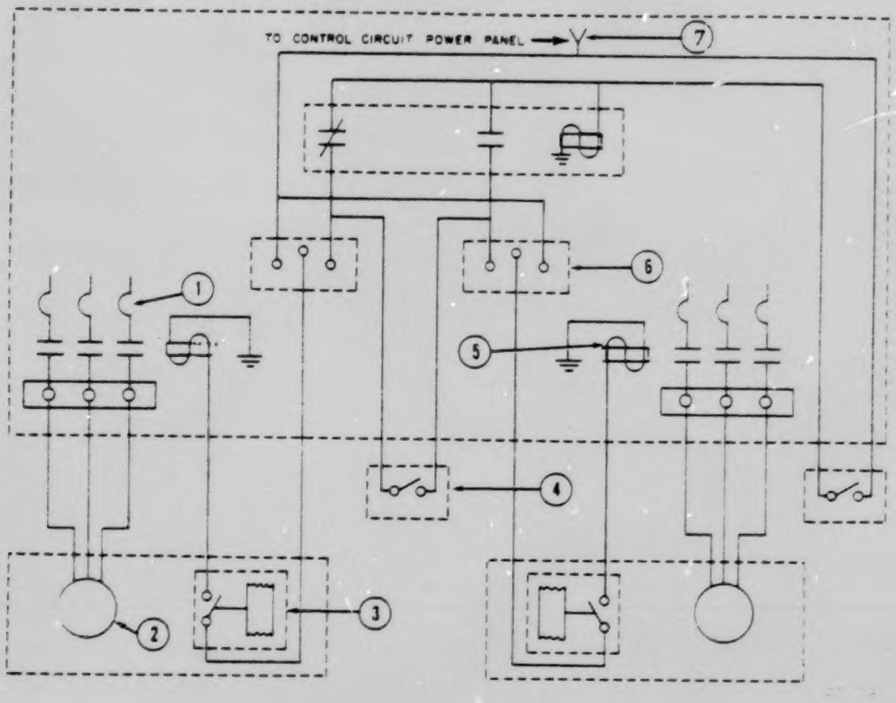
TO CONTROL CIRCUIT POWER PANEL
7
1
6
5
4
2
3

Figure 35

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________

PROJECT 2

Answer the following questions about the motor control center.

1. How many incoming power connection points will the MCC have?

2. Name four electrical components that can be found on the face of the MCC.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

3. What two types of circuit breakers may an MCC contain?

   a. ____________________

   b. ____________________

4. How is voltage distributed through the MCC?

5. What is the purpose of the door switches in the MCC?

6. What is meant by HOA switch?

PROJECT 3

Identify the numbered components on figure 36.

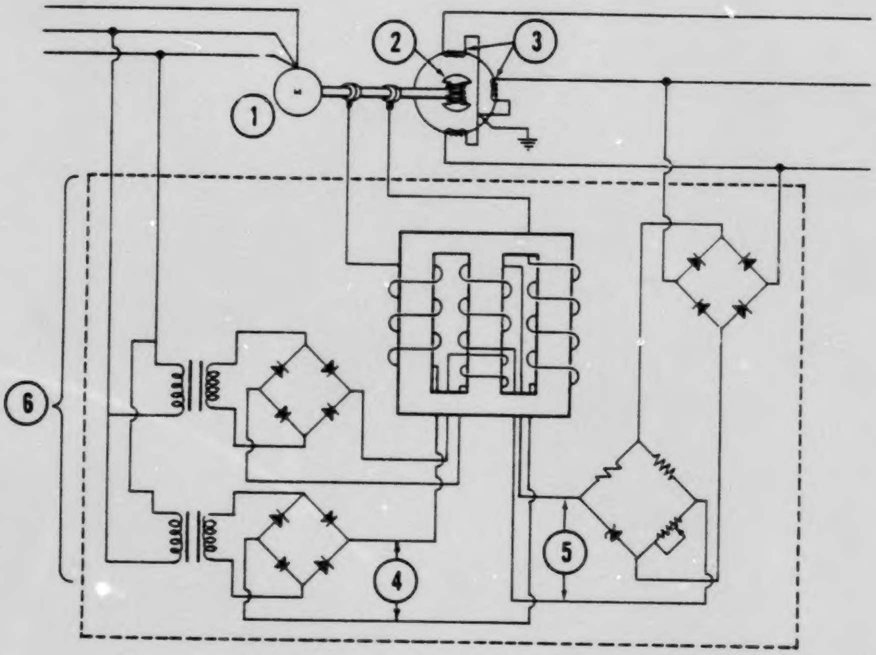

Figure 36

1. ______________________

2. ______________________

3. ______________________

4. ______________________

5. ______________________

6. ______________________

STUDY GUIDES
3ABR54230-1-V-1 thru 3

Technical Training

Electrician

CONTROLS AND ALARM SYSTEMS

August 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

Designed For ATC Course Use

DO NOT USE ON THE JOB

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(Copies of superseded publication may be used until the supply is exhausted.)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-V-1
August 1975

INTRUSION ALARM SYSTEMS

OBJECTIVE

This study guide will help you to become familiar with the types, design, operation, and components of intrusion alarm systems.

INTRODUCTION

Intrusion alarm systems are composed of protection and annunciating devices for premises protection. These devices are assembled into an integrated system for the protection requirements of various structures and/or areas. Special features are incorporated to meet the particular operating procedures and physical layout existing at a particular area.

These systems are primarily designed for the detection of unauthorized entry and supervision of authorized entry into the protected area. This protection is obtained by use of all or a combination of sound detectors, heat detectors, motion detectors, vibration detectors, door contacts, window contacts, foiling, and lacing.

The circuitry is arranged so that entry into a protected area causes the transmission of a signal to the guardhouse. This signal causes the operation of visual and audible alarm devices.

Wiring from all structures to the Central Security Control is electrically supervised against faults such as grounds, breaks, and/or a short which cause distinctive indications at the control center. See figure 1 for a block diagram of a typical intrusion alarm system.

INFORMATION

PROTECTIVE ALARM SYSTEMS

An electrical protection system applied to an area will automatically detect unauthorized entry and supervise authorized entry. Generally, the main advantage is that it removes the need for complete dependence upon the human element and permits a reduction in security force. There are other advantages, such as:

Permitting supervisory personnel to readily know of an attack.

Zoning of circuits pinpoints the alarm and permits the concentration of security force where needed most.

Supplementing the security force and permitting greater coverage with a reduced security force.

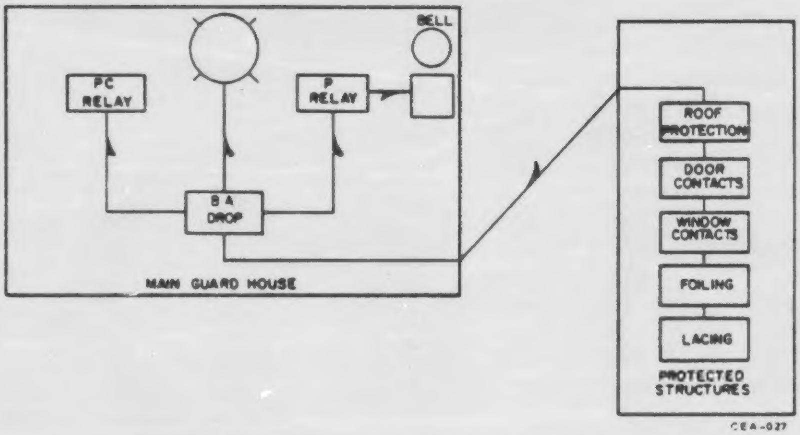


Figure 1. Block Diagram of Protection System

Basic Theory

Intrusion alarm systems consist of a number of simple direct current circuits. For you to be better able to follow the description of these circuits, three basic items will now be discussed or reviewed.

OHM'S LAW. Ohm's law states that the applied voltage to a circuit is equal to the current times the resistance. Voltage is measured in volts, current in amperes, and resistance in ohms. The symbol for voltage is E, current I, and resistance R. A pressure of one volt will cause a current of one ampere to flow through a resistance of one ohm. One ampere of current is quite a large value with respect to signal or protection circuits with which we will be dealing. Since supervisory and/or alarm current is normally below 1/20 (.05) of an ampere, we must use the term milliampere. One ampere is equal to 1000 milliamperes, and thus one milliampere is equal to 1/1000 of an ampere. When writing milliampere, use the abbreviation ma.

Ohm's law may also be expressed as follows:

$$I = \frac{E}{R} \quad R = \frac{E}{I} \quad E = IR$$

An example of the application of Ohm's law is to determine the current that will flow in a circuit where the value of the applied voltage and the resistance are known. Find the current that will flow in the circuit, shown in figure 2, with 48 volts applied and a total resistance of 3200 ohms.

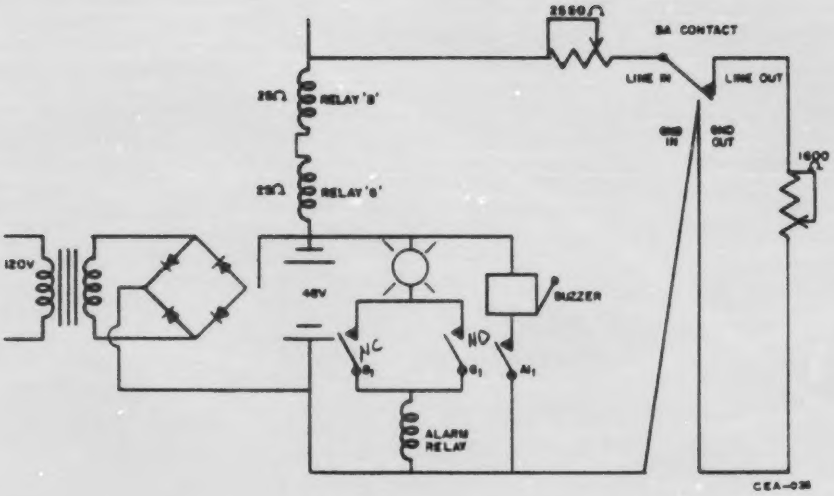


Figure 2. Basic Protection Circuit

Example: $I = \frac{E}{R} = \frac{48 \text{ volts}}{3200 \text{ ohms}} = .015$ amperes

$.015$ ampere or $\frac{15}{1000}$ amperes equals 15 milliamperes.

Thus, the answer may be expressed as 15 ma or 15 mils.

RELAY OPERATION: A relay is an electromechanical device that consists of a coil of fine wire wound around a soft iron core. This core is made of a magnetic material, a material that is capable of being magnetized. When an electrical current flows through the coil, a magnetic field is set up in and around the core. This magnetic field exists as long as current is flowing in the coil. When the current is cut off, the magnetic field collapses. The core material is soft iron, and due to its composition, loses its magnetism immediately after the current flow has stopped. The coil and core of a relay is an electromagnet. Attached to one end of the coil and core is a hinged armature. This armature is also made of soft iron so that it will be attracted magnetically but will not retain any magnetism after the field induced by the electromagnet collapses. Therefore, when the coil has current flowing through it, it attracts the armature. Since the armature is hinged, it will swing on its pivot toward the core.

The mechanical movement of the armature causes a set or several sets of electrical contacts to operate. These contacts may be normally open and close a circuit when the relay is energized. They can also be normally closed and open a circuit when the relay is energized. It is possible to have several sets of contacts, either closed or open on the same relay actuated when the armature is attracted to the core. (See figure 3, Basic Relay Components.)

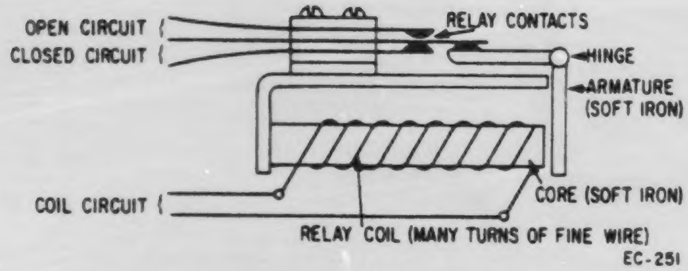


Figure 3. Basic Relay Components

The reasons for using relays are as follows:

A relatively small amount of current is required to operate a relay. Therefore, a small gage wire may be used for long distances.

One contact or switch can control a single relay which in turn can be made to perform several functions, depending on the number and type of contacts on the relay.

Since relays, depending on their design, need certain values of current to operate, they can be used to detect various conditions in a circuit.

Relays can be used to lock circuits in or out and provide a means of remote control.

DEFINITION OF TERMS. Terms frequently used when discussing intrusion alarm systems and their definitions are as follows:

B. A. Contact. Burglar Alarm Contact. Any device so placed that will actuate an alarm.

Drop or B. A. Drop. The annunciation device used on the central control unit that senses any abnormal conditions occurring in the protection circuit.

Supervised. An alarm will result when the wire is broken, grounded, or when two wires are shorted together.

Annunciation. Visual and audible signal indications received at central control points.

Break Alarm (Break Drop). An alarm created by a decrease in line current below 9 ma.

Ground Alarm (Ground Drop). An alarm created by an increase in line current to 30 ma.

Combination Break and Ground Alarm (Double-Drop). An alarm created first by a decrease in line current below 9 ma and then an increase in line current to 30 ma.

Basic Circuit

There are two distinct features which must be a part of the design of a basic protection circuit. These are: The circuit must be under constant and complete electrical supervision, and it must function with a current capable of being carried by telephone conductors.

In the typical basic protection circuit shown in figure 2, notice that in addition to the closed series protection circuit, there is also an open series annunciation (alarm) circuit in parallel across the same power supply.

The closed series protection circuit contains relays B and G (part of BA drop in central control unit), a transfer contact and two resistors. The open series annunciation circuit contains contacts of relays B and G connected in parallel and the alarm bell.

Let us now see how the circuit fulfills the requirements for constant and complete electrical supervision. We have calculated by Ohm's law that the current flow in the circuit shown in figure 2 is 15 ma. This current is sufficient to energize relay B and thus maintain its contact B1 open. If a break occurs in any portion of the circuit, relay B will deenergize, contact B1 will close and the alarm bell will operate.

If a ground occurs in any portion of the power side of the circuit, both resistors will be bypassed, and according to Ohm's law, the circuit will increase (less resistance--more current). Relay B will remain energized and relay G due to its design will energize. Its contact G1 will close and the alarm bell will operate.

If a ground occurs in the portion of the ground circuit between the two resistors, the 1600-ohm resistor would be bypassed and the current would increase to approximately 30 ma. Relay G would energize and cause annunciation as before.

If a short (cross) occurred between the two wires in any portion of the circuit, the current would increase and be annunciated by the alarm bell.

It may be seen that the circuit is completely supervised. Any accidental circuit faults result in an alarm. For all practical purposes, it is foolproof and cannot be tampered with. Any malicious tampering results in the operation of the alarm bell.

Let us see how the circuit fulfills the second basic requirement. The normal supervisory current is 15 ma, and the greatest current resulting from a trouble is 30 ma. Thus, the current in the closed series protection circuit is low and capable of being carried by small gage wire. The current in the open circuit annunciation may be quite high. This is safely handled by the contacts of the B and G relays; and since this circuit is part of the control panel, conductor size is not a problem.

CENTRAL CONTROL EQUIPMENT

Each protected area, building, or section of a large building has its own alarm circuit directly connected to the central control equipment in the guardhouse. At this point, each circuit terminates at a BA drop located on the front of the central control unit.

BA Drop

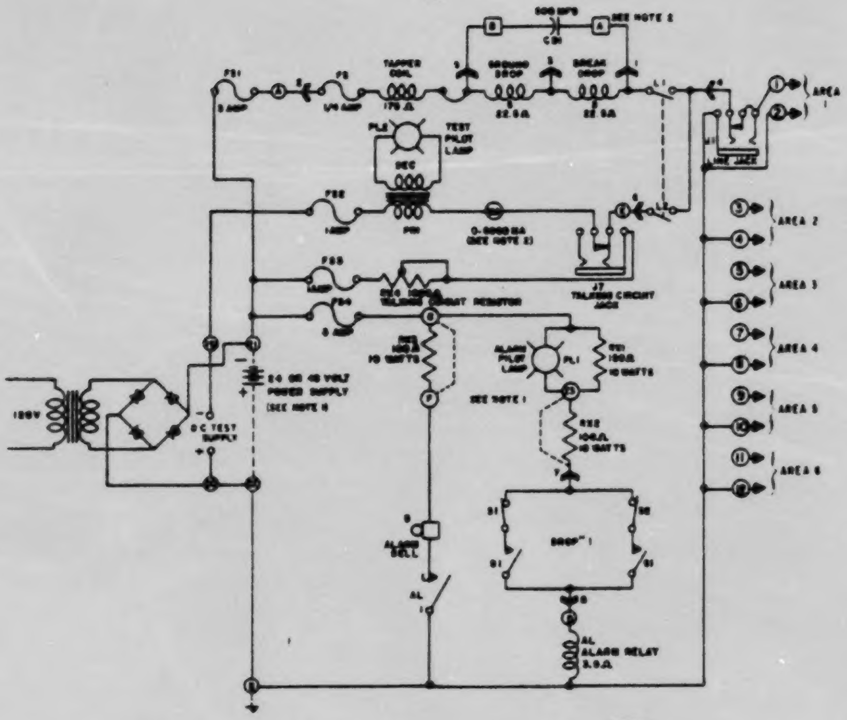
This device consists of a plug-in unit on the face of which are two small windows through which can be seen two target annunicators. Associated with each target and directly below it is a reset lever. Two telephone-type switches, one with a yellow handle (S1 and S2) and one with a red handle (L1 and L2), are located directly below the reset levers. A tapper is located between the two telephone-type switches. The "tapper" taps audibly on the inner side of the faceplate and moves visibly in and out beyond it when an authorized person at the protected structure wishes to communicate with the operator at the guardhouse. This is done by inserting the plug of the phone in the jackbox and operating the hand button located on the handgrip of the handset. The tapper rod is mechanically attached to the armature of the tapper coil, which is located at the rear of the BA drop. With normal night current of 15 ma, the tapper coil is deenergized, and the tapper is flush with the faceplate. With alarm current of 30 ma, the tapper coil is energized, and the tapper extends out from the faceplate. Inside the housing are two galvanometer movements, break and ground, which are attached to each target by an operating arm. At one end of these arms are the targets, at the other end are a set of contacts (G1 and B1). The targets are reset out of view; these contacts are open. When the targets are in view, these contacts are closed. Each galvanometer movement has a coil (ground coil and break coil) which are wired in series. These coils are connected in series with the tapper coil and the line switch on the drop, the alarm devices in the protected structure and the power supply. The circuit components are adjusted to produce 15 ma normal current. The alarm devices are capable of either reducing the current to zero and/or increasing the current to 30 ma by opening and/or crossing the line.

The signals received on the BA drops may be of four distinct types:

1. A break in the protection circuit, causing the break target on the drop to show.
2. A short in the circuit, causing the ground target to show.
3. A combination break and cross, causing both targets to show.
4. The tapper coil is energized between 18-22 ma.

All types of above signals result in both an audible and visual signal at the guardhouse in the form of a buzzer and red pilot light. All signals received are treated as alarm signals as this equipment will not differentiate between an alarm and a trouble signal. Quite often a trouble signal is the result of malicious tampering.

BREAK. When the circuit is broken, the c rrent falls below 9 ma, contact B1 closes and break target comes into view. Upon closing, contact B1 establishes a circuit through alarm relay (AL) and a red pilot light on the panel. This light operates and contact AL1 closes, causing the vibrating buzzer to sound. (Refer to figure 4.)



500 MFD
B
A
SEE NOTE 2
CBI
FS1
3 AMP
2
FS
1/4 AMP
TAPPER COIL
175 Ω
3
GROUND DROP
22.5 Ω
5
BREAK DROP
22.5 Ω
1
L1
4
AREA 1
LINE JACK
PL2
TEST PILOT LAMP
SEC
PRI
FS2
1 AMP
0-5000 MA (SEE NOTE 2)
6
L2
J7
TALKING CIRCUIT JACK
FS3
1 AMP
TALKING CIRCUIT RESISTOR
FS4
3 AMP
AREA 2
AREA 3
AREA 4
AREA 5
AREA 6
RE3
100 Ω
10 WATTS
ALARM PILOT LAMP
PL1
RE1
100 Ω
10 WATTS
SEE NOTE 1
RE2
100 Ω
10 WATTS
7
120V
D C TEST SUPPLY
24 OR 48 VOLT POWER SUPPLY (SEE NOTE 1)
8
ALARM BELL
AL
S1
S2
DROP 1
AL
ALARM RELAY
3.0 Ω

NOTES 1 THIS UNIT AS SUPPLIED IS FOR A 48 VOLT OPERATION WHEN A 24 VOLT POWER SUPPLY IS USED. THE JUMPERS SHOWN DOTTED ACROSS THE 100 OHM RESISTORS (RE2 AND RE3) SHOULD BE INSTALLED.

2 THE UNIT SHOWN IS WIRED FOR POSITIVE GROUNDED BATTERY. IF NEGATIVE GROUNDED BATTERY IS USED, REVERSE WIRING TO CONDENSER BY CONNECTING WIRE LABELED B TO PLUS ON CONDENSER AND WIRE A TO MINUS ON CONDENSER AND REVERSE CONNECTIONS TO METER

3 TERMINALS A, B, C, D, AND E ARE PROVIDED FOR CONNECTIONS TO A 85804-CA AUXILIARY CONTROL UNIT. IF REQUIREDCONNECT A TO A B TO B, ETC.

LEGEND

○	TERMINALS OF 85804--C CONTROL UNIT
—<	INTERCONNECTING SOCKET AND PLUG
FS1	LINE FUSE
FS2	TEST FUSE
FS3	TALKING—CIRCUIT FUSE
FS4	LOCAL ANNUNCIATOR FUSE
L1, L2	LINE SWITCH CONTACTS OF DROP
S1 S2	LOCAL SWITCH CONTACTS OF DROP

EC-252

Figure 4. Typical Circuit for Central Equipment

Operating the silence switch (yellow handle) to the left opens contact S1 which silences the alarm buzzer and extinguishes the red pilot light. The break target cannot be reset until circuit current returns to 15 ma. The silence switch should be restored to its center position when the break target is reset.

CROSS. When the circuit is crossed, the shunting of the night resistor in the protected structure, causes the current to increase to 30 ma. Contact G1 closes and the ground target comes into view. Upon closing, contact G1 establishes a circuit through alarm relay (AL) and a red light on the panel. The light glows and contact AL1 closes, causing the alarm buzzer to sound. (See figure 4.)

When the silence switch (yellow handle) is operated to the right, contact S2 will open, silencing the alarm buzzer and extinguishing the red pilot light. The ground target cannot be reset until the circuit current is down to 15 ma. The silence switch should be restored to its center position when the target is reset.

BREAK AND CROSS. The circuit is first broken and then crossed almost simultaneously. When the circuit is broken, contact B1 closes, and as described before, the red light and buzzer operate. When the circuit is crossed, contact G1 closes and establishes another path for the annunciation circuit.

The break target may be reset as the protection circuit is completed through ground with a current flow of 30 ma. The ground target cannot be reset due to this current value.

When the break target is reset, contact B1 opens; but the buzzer and red light remain in the operated condition through contact G1. Operation of the silence switch to the right opens contact S2 and silences the alarm buzzer and extinguishes the red pilot light. When the circuit is restored to normal, the ground drop should be reset and the silence switch restored to its center position.

Circuit Description

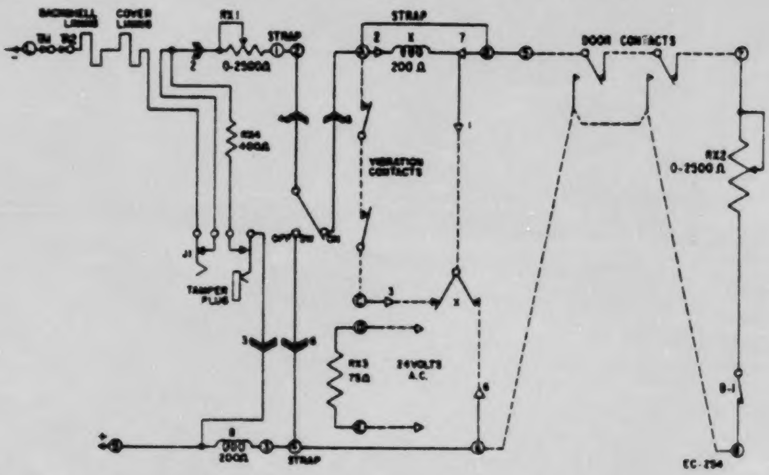
Signals from the various protection circuits are received on galvanometer relay units (BA drops).

The protection circuits from the various protected structures are connected to individual BA drops located on the front of the switchboard. These drops are mounted in horizontal rows of four drops each. There is a common alarm light associated with each row to aid in quickly locating the operated drop.

Reference should be made to figures 4 and 5 in conjunction with the following descriptions of typical normal protection, alarm, test, communication, and talking circuits.

NORMAL PROTECTION CIRCUIT. The circuit from the source of power enters terminal 21, of the central control unit, figure 4. The circuit then continues through fuse FS1 (3-amp) to terminal A. Then the circuit enters terminal 2, and a 1/4-amp fuse located to the rear of the BA drop. The circuit continues through the tapper coil, ground coil G, Break coil B, through line switch L1 (RED) through terminal 1, of the Central Control to the protected structure through a telephone communication circuit.

The circuit continues to: terminal L (Line) of figure 5, to TA1 (pry-off tamper switch), TA2 (door tamper switch), backshell lining, cover lining, J1 (communication jack) terminal 2, RX1 day resistor, terminals 1 and 2, to the ON portion of on-off switch, terminal A, through the vibration contacts, to the "X" contact, terminals B and 5, through door contacts to terminal 7, through night resistor RX 2, to B1 test bell contacts, terminal 8, terminals 6, 4, 3, test bell coil B, terminal 9, then in figure 4 to terminals 2, B, 22, and back to the source of power.


BACKSHELL LINING
COVER LINING
TA1 TA2
RX1
0-2500Ω
STRAP
STRAP
2
X
7
200 Ω
DOOR CONTACTS
RX4 400Ω
VIBRATION CONTACTS
RX2 0-2500 Ω
J1
TAMPER PLUG
OFF ON
3
4
RX3 75Ω
24VOLTS A.C.
6
B-1
B
200Ω
STRAP
EC-294

LEGEND

○	Terminal of 5912-CL Control Unit
△	Terminal of eight-point socket
—➤—	Plug and socket connection
—·—·—	Internal wiring of "X" relay
– – –	Installers Wiring
	B-coil of test bell
	B1-test bell contact
	J1-telephone jack

RX1-Line resistor
RX2-Night resistor
RX3-Heater resistor
RX4-Current limiting resistor
SW-Protection on-off switch
TA1-cabinet pry-off tamper
TA2-cabinet door tamper
X-Plug-in alarm relay

NOTES:

1. Circuit shown in normal PROTECTION ON condition.
2. Plug-in relay X is required if vibration contacts are connected in the circuit.
3. If relay X is used, remove strap between terminals A and B.
4. Terminals D and E should be connected to 24 volts ac in locations where heat is required to prevent condensation.
5. If B.A. screens or lacing is to be connected in the circuit, remove straps between terminals 1 and 2 and 3 and 4, connect high side between terminals 1 and 2 and low side between terminals 3 and 4.
6. If B.A. foil is to be connected in the circuit, remove the strap between terminals 1 and 2 and connect accordingly, follow the same procedure if other tampers are to be connected in the circuit.

Figure 5. Schematic of Security Alarm System Local Control Unit

ALARM CIRCUIT. The normal 15-mil (milliamps) current is sufficient to energize the break coil, and keep its target from view, but not sufficient to energize the ground coil. When normal current drops below 9 mils, the break coil deenergizes, its target moves into view and contact B1 closes. When contact B1 closes, a circuit is established from power through the coil of alarm AL on the control panel to point 8 on the drop plug, contact B1 and silence switch (yellow handle) contact S1 to plug 7, through the alarm pilot with parallel 150-ohm resistor, a 100-ohm series resistor, through a 3-amp fuse on the control panel to power. The alarm relay energizes and the alarm pilot lights (red). Contact AL closes, energizing alarm buzzer on the control panel, causing it to operate.

The operator then moves the yellow-handled silence switch to the left, opening contact S1 which silences the buzzer and extinguishes the pilot light. Contact B1 of the drop remains closed as the break target cannot be reset until the circuit current increases above the 9-mil point and energizes the break coil.

If the normal current increases to 30-mils, the ground coil of the drop energizes, its target moves into view and contact G1 closes, establishing the same circuits as previously described, except that this time the circuit is established through contacts S2. The operator moves the yellow-handled silence switch to the right, opening contact S2, silencing the alarm buzzer, and extinguishing the pilot light. Contact G1 remains closed as the ground target cannot be reset until the circuit current decreases below the 21-mil point and deenergizes the ground coil.

Some protection devices will, upon operation, cause the protection circuit to first be broken and then crossed (shunting out the night resistor in the local control unit and increasing the current to 30-mils) almost simultaneously. When the circuit is broken, contact B1 closes and the red light and buzzer operate. When the circuit becomes crossed, contact G1 closes and establishes a parallel path for the alarm annunciation circuit. The break target may be reset immediately as the cross on the protection circuit, causing a 30-mil current to flow, energizing the break coil.

When the break target is reset, contact B1 opens, but the buzzer and light remain operated through contact G1. Operation of the silence switch to the right opens contact S2 and thus silences the buzzer and extinguishes the light. When the circuit restores to normal, with 15-mil current flowing, the ground coil deenergizes. The ground target may be reset and the silence switch restored to its normal center position.

TEST CIRCUIT. Rectified ac power is provided for individually testing the protection circuits. Selectivity is obtained by manipulation of the line switch on the BA drop in the particular protection circuit.

When the line switch (red handle) is operated to the right, contact L1 opens and contact L2 closes. This transfers the high-side of the protection from its normal 48-volt power source through the break and ground drops, to a 135-volt test power source. The test circuit may be traced from the negative through the power set, a 1-amp fuse, the primary of the test transformer on the control panel, the milliammeter on the test panel, contact L2 and through the line jack to the protected structure. The circuit is completed through the local control unit normal protection citcuit located at the protected structure, causing the bell coil to ring at the protected structure, and the test light to glow and milliammeter to respond at the central control indicating a normal circuit.

"Talking Circuit"

A common "talking" circuit may be provided for communication over the transmission lines. Selectivity is obtained by operating the line switch to the L2 position on the particular BA drop, after the telephone handset is plugged into the communication jack at the central control unit.

Jackboxes must be installed in each local control unit for authorized personnel to plug-in a portable telephone handset. This enables the maintenance man to signal and talk to the switchboard operator.

The maintenance man removes the tamper plug from the jackbox at the local control unit and plugs in his handset. A ground alarm is received on the particular BA drop when the tamper plug is removed. A break alarm is registered when the handset is inserted. The maintenance man signals the operator by intermittently operating the pushbutton in the handle of the phone. This button opens and closes the protection circuit, annunciates an alarm condition, and operates the tapper coil on the particular BA drop.

The visual and audible operation of the tapper is a distinctive feature which identifies the annunciation as a communication signal rather than an alarm signal.

The switchboard operator plugs his telephone handset into the communication circuit jack at the central control unit, operates the line switch (L2) to the right position, and the "talking" circuit is thus established for two-way communication.

When the conversation is completed, the maintenance man removes his handset and restores the protection circuit to normal by replacing the tamper plug.

The switchboard operator returns the line switch (L1) to the left position and removes the telephone handset from the "talking" jack and resets the break and ground targets.

CENTRAL CONTROL UNIT (B5904C)

The control unit provides for the control, annunciation, and testing of the protective alarm system circuits. There are various types of control units which can be used, depending on the scope of protection desired. The type discussed here is the one you will be associated with in this course. It is 18" wide, 18" high, and 7" deep, with a hinged cover. The cover of the cabinet has cutouts to accomodate a maximum of six BA drops. The cover of the cabinet contains a line jack for each drop position, a common "talking" jack, a test milliammeter, a test pilot light (amber), and a common alarm red light.

The wiring at the rear of the cover contains six, 10-point sockets, on short cables, each of which is provided for attaching to a particular BA drop.

Local Control Unit 5912-CL

This unit, designed for installation outside the protected structures, is the control unit to which the alarm initiating devices are connected. The unit consists of a gray finished steel cabinet, (approximately 12" high, 5 1/2" deep, 8" wide) inside of which is mounted a control panel. The unit is lined and provided with a cover tamper switch and a pry-off tamper switch. The cover contains a three-position rotary switch for conditioning the protective circuit to the ON or OFF condition, a jack for inserting a portable telephone handset for communication and a tamper plug attached to a chain.

The control panel contains two variable resistors for adjusting the circuit currents, a test bell, a resistor for providing heat, a socket for inserting an alarm relay,and two terminal strips for external wiring connections. (Refer to figure 5.)

The test bell is operated at closing time (and periodically during the protection ON period) by applying a test potential, at the Guardhouse, to the protection circuit. If the circuit continuity is complete the test bell will operate.

Terminals are provided to connect 24-volts ac to the resistor on the control panel if heat is required to prevent condensation within the unit.

An alarm relay must be ordered separately and inserted in the socket on the control panel if vibration contacts are connected to the protection circuit. The relay is a five-prong plug-in relay with a 200-ohm coil and a set of transfer contacts.

The unit is designed for wall mounting and is provided with 1/2" and 3/4" conduit knockout at each side. The unit is not weathertight and must, therefore, be mounted in a suitable outdoor housing.

The test bell is factory adjusted and should not require any field adjustment. After the unit is installed and all the protection devices connected, the line currents should be adjusted.

After the unit is installed and the initial line and bell current adjustments are made, the unit will require little attention. The contacts on the spring pileups of the jack should be burnished at least every three months.

Local Control Unit B179

This unit, designed for installation inside the protected structures, is the control unit to which the alarm initiating devices are connected. It is 7 7/8" high X 4 3/8" deep and consists of a phenolic housing with a removable cover. The cover contains a three-position rotary switch for conditioning the protection circuit to the ON or OFF condition. The cover also contains two pin plugs which are electrically connected within the phenolic material. These plugs engage mating jacks in the base of the cover and both the plugs and jacks are wired into the circuit, in such a manner, as to open the protection circuit when the cover is removed, figure 6.

The unit also contains two variable resistors for adjusting the circuit currents, a terminal strip for external wiring connections and a test bell. The test bell is operated at closing time (and periodically during the protection "On" period) by applying a test potential, to the protection circuit at the Guard House. If the circuit continuity is completed, the buzzer in the B179 unit will operate.

No provisions are made for running conduit to this unit and therefore, it must be mounted on a Conduit Base. This base is approximately 1-1/2" deep and is provided with a tapped hole for 1/2" conduit at the top and bottom of this unit.

The test bell in this unit is factory adjusted and should not require any field adjustment. However, the location of the bell dome is an essential part of the adjustment and it must be removed in order to mount the unit. Therefore, the bell dome should be marked before removing and should be carefully replaced in order not to affect the adjustment.

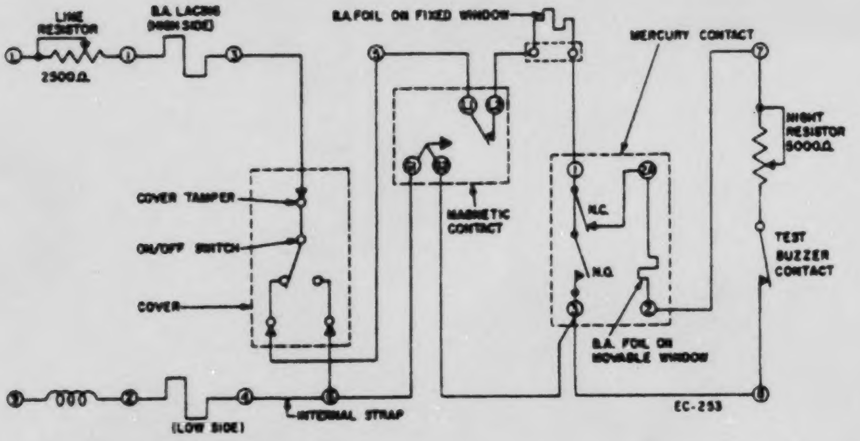

LINE RESISTOR
2500Ω
B.A. LACING (HIGH SIDE)
B.A. FOIL ON FIXED WINDOW
MERCURY CONTACT
NIGHT RESISTOR 5000Ω
COVER TAMPER
ON/OFF SWITCH
COVER
MAGNETIC CONTACT
N.C.
N.O.
TEST BUZZER CONTACT
B.A. FOIL ON MOVABLE WINDOW
(LOW SIDE)
INTERNAL STRAP
EC-253

Figure 6. B179 Local Control Unit

BA (BURGLAR ALARM) CONTACTS

Vibration Contact

In figure 5, the component parts of the unit are molded and/or assembled to a phenolic base. A phenolic cover is secured to the base with two screws and sets on a cork dust sealing gasket. The unit consists of a set of normally closed contacts. The stationary contact is molded in the base; the moving contact consists of a thin, flexible steel reed with a small weight riveted to the end. A pressure spring is attached to the steel reed and is provided with an adjusting screw. Two two-foot leads are soldered to terminals in the bottom of the base. A bottom cover is installed over these terminals to insulate them from metal surfaces.

The unit should be mounted so that the leads face downward to prevent the possibility of water and/or dirt accumulating in the wiring recesses and to assure proper operation of the contact.

A connecting block, for use as a test point, must be mounted near each vibration contact, so that a meter may be inserted in the circuit to observe the results of the tests. The metal strip supplied with the block should be replaced with a wire strap to facilitate opening the circuit for inserting the test meter.

The vibration circuit is normally closed and is wired to shunt the alarm relay in the relay unit; which is required whenever vibration type contacts are used. The vibrations which occur during an attack cause the steel reed to vibrate, open the normally closed circuit,and thus energize and operate the relay unit and the alarm set to produce a locked-in ground at the guardhouse.

The contact is factory adjusted for a contact pressure of four to six grams. In theory, each contact should be adjusted to a certain maximum sensitivity to assure receipt of an alarm upon minimum attack vibrations and a certain minimum sensitivity in order that false alarms may be eliminated. The minimum pressure setting for the contact should normally be one gram.

The sensitivity is adjusted by changing the contact pressure. Turning the pressure adjusting screw clockwise will increase the pressure on the contacts and decrease the sensitivity. Turning the pressure adjusting screw counterclockwise will decrease the pressure on the contacts and increase the sensitivity.

Contact pressure shall be measured with a gram gage. An approximate separation of not less than 1/32 inch must be held between the two springs. This will allow proper freedom of movement for the weighted contact. Never bend the springs of the contacts. If defective for any reason, replace it with a new unit.

Magnetic Contact

In figures 5 and 6, the magnetic contracts are primarily used for heavy-duty swing doors, track doors, and gates. These contacts consist of two parts, an actuating block and a contact block, each enclosed in a weatherproof housing. The magnet is mounted on the door to be protected and the contact block is mounted on the door head or frame in such a manner that when the door is closed, the magnet and contact block are brought together. The air gap between the two parts of this contact (magnet and contact block) should be from 1/4 to 1/2 inch. A tapped hole for 1/2-inch conduit is located at one end of the contact block. A removable cover plate is provided for access to the wiring terminals.

This unit will not require adjustment. On rare occasions, the contact within the contact block may become inoperative. When this happens, the contact unit should be replaced. It would not be necessary to remove the contact block to replace this unit.

The contact unit consists of two pole pieces and a rotor pivoted between the pole pieces. Attached to the rotor is a metal strip with contact points which mate with fixed contact points on the pole piece as the rotor pivots. A spring attached between one end of the rotor and a fixed bracket keeps the rotor in position so that one of its contact points engages a pole piece contact point and maintains a closed circuit. When a strong magnetic field is introduced near the contact block (door closed), the rotor will pivot due to its irregular shape, since the lines of magnetic flux will seek the shortest path through iron. The rotor is pivoted by this magnetic force and in so doing charges the torsion spring. The pivoting of the rotor transfers the rotor contact point from one pole piece contact point to the other pole piece contact point. This device is in effect a single-pole, double-throw switch. When the magnetic field is removed (door opened), the rotor is pivoted by the torsion spring and the contacts transfer, initiating a break alarm and then a ground alarm.

Mercury Contact

In figure 6, this device consists of two single-action mercury switches mounted in an adjustable clip and enclosed in a phenolic housing. These switches are mounted so that the contacts of one are normally open (make contact) and the other normally closed (break contact). Screw terminals are provided for connecting the line wiring; clips are provided under the heads of the terminal screws for connecting the window foil, see figure 3.

The switches should be adjusted to operate when the surface on which the contact is mounted is tilted through an angle of two degrees.

This contact is used for protection of tilting windows such as horizontally pivoted windows or the cantilever projected type.

When the window on which a mercury contact is mounted is tilted, the mercury in the normally closed switch flows away from the contacts while the mercury in the normally open switch flows toward the contacts. The break contacts are opened and the make contacts are closed due to the action and conductance of the mercury. This action is in effect equivalent to a transfer contact and results in a break followed by a ground on the circuit.

SUMMARY

An intrusion alarm system applied to an area will detect unauthorized entry and supervise authorized entry. The main advantage is that it removes the need for complete dependence upon the human element and permits a reduction in guard force.

These systems consist of a number of simple direct current circuits. Since supervisory and/or alarm current is normally below .05 of an ampere, we must use the term milliampere. One ampere is equal to 1,000 milliampers and one milliampere is equal to 1/1,000 of an ampere. The common abbreviation for milliampere is ma.

A relay is an electromechanical device that consists of a coil of fine wire wound around a soft iron core, made of a magnetic material. Due to the composition of the core, the armature materials, they lose their magnetism immediately after current ceases flowing in the coil and the magnetic field collapses.

The mechanical movement of the armature, because of its attraction to the core of a relay, will cause a set or several sets of electrical contacts to operate. These contacts may be normally open and close a circuit when the relay is energized, or they may be normally closed and open a circuit.

Relays are used because a relatively small amount of current is required for their operation, permitting the use of small gage wire for long distances.

One contact or switch can control a single relay which, in turn, can be made to perform several functions depending on the number and type of contacts on the relay.

Since relays, depending on their design, need certain values of current to operate, they can be used to detect various circuit conditions.

There are two distinct features which must be incorporated in the design of a basic protection circuit. These are: the circuit must be under constant and complete electrical supervision, and it must function with a current capable of being carried by telephone conductors.

In direct wire intrusion alarm systems, each protected area, building, or section of a large building has its own alarm circuit directly connected to the central control equipment in the guardhouse. Each circuit terminates at a BA drop mounted in the control unit.

A BA drop consists of a plug-in unit on the face of which are two small windows through which can be seen two target indicators.

Associated with each target and directly below it is a reset lever. Two telephone-type switches, one with a yellow handle and one with a red handle, are located directly below the reset levers.

Signals received on the BA drop may be of three distinct types:

1. A break in the protection circuit, causing the break target on the drop to show.
2. A cross in the circuit, causing the ground target to show.
3. A combination break and cross, causing both targets to show.

QUESTIONS

1. What is the purpose of intrusion alarm systems?
2. What is the main advantage of these systems?
3. Why are so many relays used in intrusion alarm systems?
4. What are the four distinct indications received on BA drops?
5. What does the term supervised mean in connection with intrusion alarm systems?
6. How does a decrease in a circuit's resistance affect the current flow?
7. What distinct features must an intrusion alarm protection circuit possess?
8. What are the three expressions of Ohm's Law?
9. What is the cause of a ground target on a protection circuit's BA drop?

FIRE ALARM SYSTEMS

OBJECTIVE

The objective of this study guide is to help you become familiar with fire alarm systems.

INTRODUCTION

A fire alarm system serves the primary function of warning personnel that an overheated condition or an actual fire exists. While fire is one of man's oldest tools, it is also one of his most deadly enemies. The fire toll each year in lives and property is tremendous. Fires have killed more people in this country than wars. It is obvious that detection and control of fires are of grave concern to the Air Force. This study guide is to help you keep alarm systems in serviceable condition by detecting and correcting possible causes of failures in operation in either manual or automatic systems.

INFORMATION

PURPOSE OF FIRE ALARM SYSTEMS

Fire alarm systems provide a direct, intelligible, and reliable means of summoning the fire department to a fire, thus reducing the interval between the time a fire is detected and the time proper firefighting equipment arrives on the scene. It also warns the occupants of the structure that a fire condition exists so that they may take action to remove themselves from danger. Some types of fire alarm systems automatically detect fires and transmit alarm signals. Other systems, such as sprinkler or deluge systems not only detect and transmit an alarm signal but also begin to extinguish the fire automatically before firefighters arrive.

TYPES OF FIRE ALARM SYSTEMS

Fire alarm systems are classified as either coded or uncoded according to the type of signal transmitted. This classification is further broken down into manual or automatic, depending on the method of actuation.

Coded System

Coded systems transmit, record, and sound a signal identifying the transmitter or actuating device from which the signal originates.

Noncoded System

Noncoded systems sound a continuous signal and indicate through visual devices the circuit in which the actuating device is located.

Manual System

In manual systems other than fire reporting telephones, signals originating from fire alarm boxes may produce either coded or noncoded signals.

Automatic System

Automatic fire alarm systems may produce either coded or noncoded signals. Detectors in the system operate automatically in response to flame, or abnormally high temperatures. These systems may also have manual stations to permit manual transmission of fire alarms.

THEORY OF OPERATION

Most automatic fire alarm systems operate by varying the current flow through a network of circuits. Current flow is changed in intensity (amount) by changing either the voltage applied to the circuit or the resistance in the circuit. The amount of resistance in the circuit can be increased or decreased by relays adding or removing resistors by varying grid voltages to tubes or by changing the characteristics of the circuits.

Fire alarm circuits are normally operated using dc voltage and obtain their power from a commercial alternating current voltage system through a transformer-rectifier. Usually a battery or series of batteries are used for backup or standby supply for the system in case of an ac power failure, figure 5.

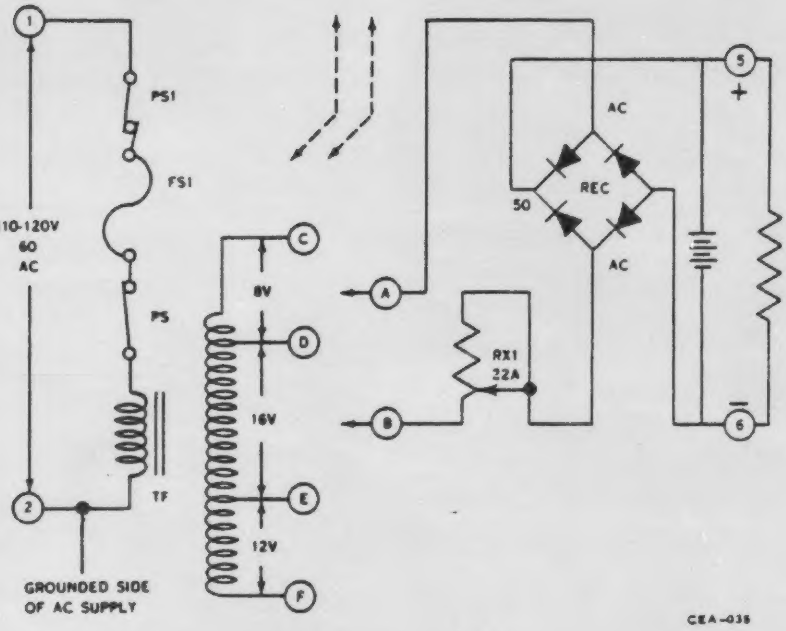

1
2
110-120V
60
AC
PS1
FS1
PS
TF
GROUNDED SIDE
OF AC SUPPLY
C
D
E
F
8V
16V
12V
A
B
RX1
22A
AC
REC
50
AC
5
+
6
−
CEA-036

Figure 5. Schematic Wiring Diagram of Power Set

Figure 5, is a schematic wiring diagram of the power set. Power at 120-volts 60-cycle ac is fed through terminals 1 and 2 of the power source, switch PS1, fuse FS1, and to the primary of transformer TF. There are four tap terminals on the secondary of the transformer which are identified on the terminal strip of the rectifier units as C, D, E, and F. The number of cells in the battery determines the terminal to which the rectifier input terminals A and B are connected.

The secondary voltage from the transformer is adjusted by rheostat RX1 and is impressed across the bridge-connected selenium rectifier. The rectifier voltage is connected in parallel with the battery voltage through terminals 5 (positive) and 6 (negative) and the input to the resistor blocks as shown in figure 5.

Automatic Heat Detector

RATE-OF-RISE PRINCIPLE OF OPERATION. When a fire occurs, air temperature rises rapidly, especially at the ceiling of an enclosure. This rapid rise of temperature, 15 to 20 degrees or more per minute, affects the Automatic Heat Detector Unit. The air in chamber (A), see figure 6, is expanded, reacts against thin flexible metal diaphragm (C) which moves spring (D) to close an electrical circuit with screw (E).

A passage leads from chamber (A) to the atmosphere in which there is a factory-installed, predetermined, trouble-free vent (B). This vent is calibrated, set and sealed at the factory to allow, under normal temperature variations, a balanced relationship between the air in chamber (A) and the outer surrounding atmosphere. This "breathing action" allows the chamber to "ride through" normal air changes.

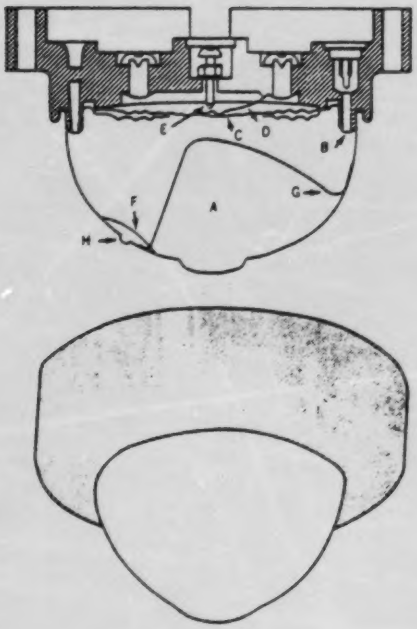


Figure 6. Automatic Heat Detector or Thermostat Unit

FIXED TEMPERATURE PRINCIPLE OF OPERATION. Completely independent of the "rate-of-rise" feature, the "fixed-temperature" principle utilizes a metallic spring (G), held to inactive position by a temperature-rated fusible alloy (F). Thus, should the "rate-of-rise" feature not respond where smoldering fires create slow temperature increases, when the heat at the ceiling reaches the fusing temperature of the alloy (F), spring (G) is released. This action then moves spring (D) to close electric circuitry with screw (E). Temperature ratings are 135 and 190°F. Selection is important, being determined by the maximum ambient air temperatures, known and anticipated, at the detector unit under normal conditions.

TELL-TALE INDICATOR. When the heat detector unit is operated by the "fixed-temperature" feature, the unit cannot be reset and must be replaced. A unique tell-tale indicator (H) of figure 6 is provided in such instances. Looking like a small "button" on the outside of the chamber, this button becomes a hole when the alloy (F) is melted. This arrangement makes it possible to readily detect a unit which has been activated.

Fire Alarm Box

The manual fire alarm box is an open circuit contact device operated by pulling a die-case handle which breaks a glass retaining rod. See figure 7. The handle, in turn, holds the switch plunger depressed against spring tension so that the switch contact is open. When the handle is pulled, the switch plunger moves forward to close the switch contacts. The box is tested by rotating the eccentric glass rod retainer one-half turn so as to release the rod and allow the switch plunger to move forward. After each fire alarm, the glass rod must be replaced. This is done by rotating the rod retainer to a certain position which will allow insertion of the rod. After insertion, the rod retainer is returned to its normal position.

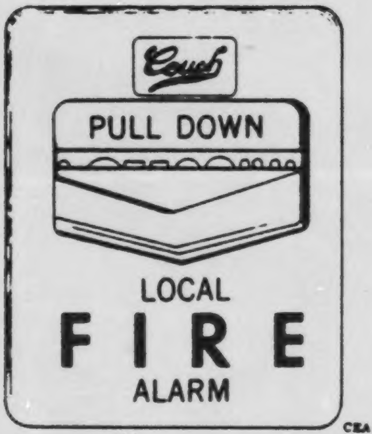


Figure 7. Manual Fire Alarm Box

CIRCUIT ANALYSIS

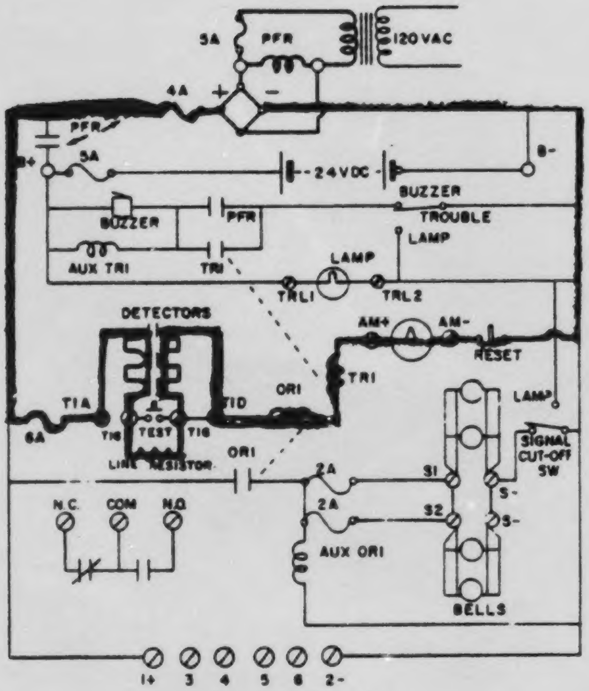
Figure 8, Local System shows the circuit in a normal supervisory condition. This means that the normal power supply is feeding power to the system and that there are no troubles or alarms in the system.

Current is flowing through the one portion of the circuit, arming the trouble and operating coils but without sufficient current to activate the relay. Current is reduced by the line resistor.

An ac power failure will deenergize the power failure relay (PFR) causing its contacts to change position. This will open the mainline contacts and close the B+ and trouble buzzer line contacts. This will connect the battery into the system at B+ and B- and energize the buzzer to let you know there is trouble, see figure 9.

A fire signal will occur when an overheat condition causes one of the detectors to close. When the detector closes, the line resistor is bypassed, reducing the total resistance of the circuit. A reduction of total resistance will cause an increase in current. This increase in current will be great enough to energize the trouble relay (TRI) and the operating relay (ORI) through the zone circuit. When the ORI relay energizes, the ORI contacts close providing a path for the signal bells, see figure 10. When the TRI relay contacts close, a path is provided through the trouble buzzer switch through the TRI contacts and through the trouble buzzer, indicating a fire condition exists.

AC



5A
PFR
120 VAC
4A
+
−
PFR
B+
5A
24 VDC
B−
BUZZER
TROUBLE
BUZZER
PFR
LAMP
LAMP
AUX TRI
TRI
TRL1
TRL2
DETECTORS
AM+
AM−
RESET
TRI
T1A
T1D
ORI
LAMP
6A
T1G
TEST
T1G
LINE RESISTOR
ORI
SIGNAL CUT-OFF SW
2A
S1
S−
2A
S2
S−
N.C.
COM
N.O.
AUX ORI
BELLS
1+
3
4
5
6
2−

LOCAL SYSTEM (EDWARDS)

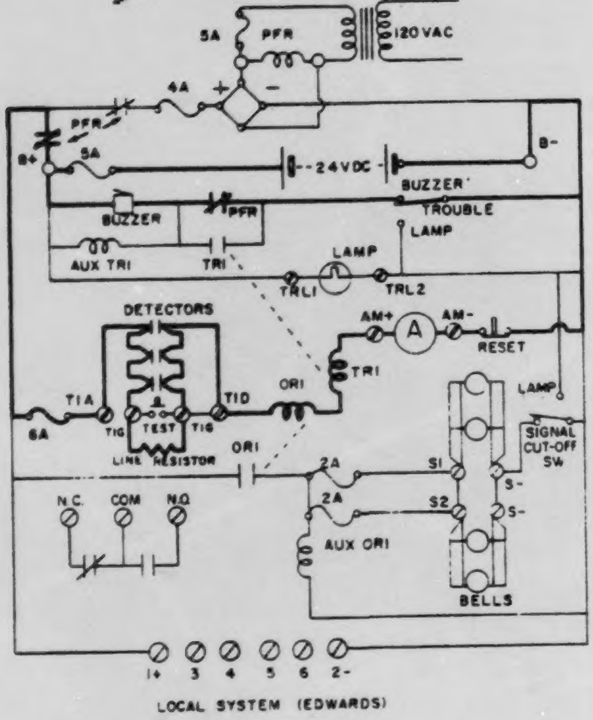
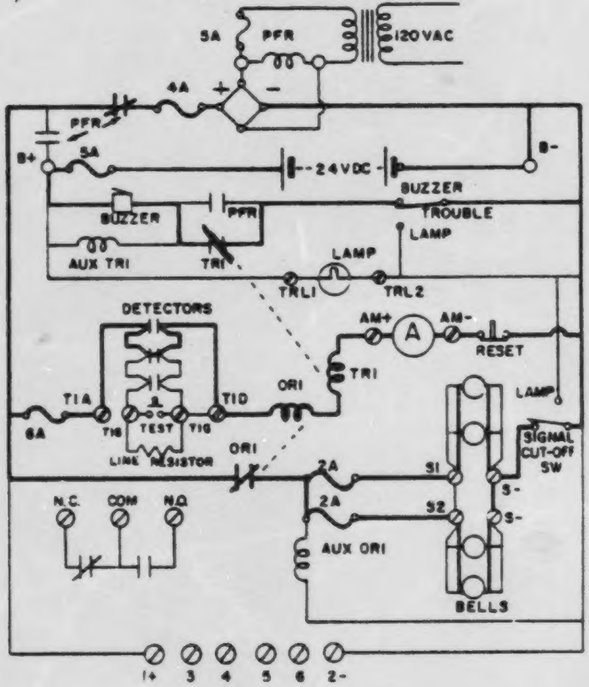

5A
PFR
120 VAC
4A
+
-
PFR
B+
5A
24 VDC
B-
BUZZER
BUZZER
PFR
TROUBLE
LAMP
AUX TRI
TRI
LAMP
TRL1
TRL2
DETECTORS
AM+
A
AM-
RESET
TRI
LAMP
TIA
TID
ORI
6A
TIG
TEST
TIG
LINE RESISTOR
SIGNAL CUT-OFF SW
ORI
2A
S1
S-
2A
S2
S-
N.C.
COM
N.O.
AUX ORI
BELLS
1+
3
4
5
6
2-
LOCAL SYSTEM (EDWARDS)

Figure 9. Local System

ALAR!!


5A
PFR
120VAC
4A
+
−
PFR
B+
5A
24VDC
B-
BUZZER
TROUBLE
BUZZER
PFR
LAMP
AUX TRI
TRI
LAMP
TRL1
TRL2
DETECTORS
AM+
A
AM-
RESET
TRI
T1A
T1G
TEST
T1G
T1D
OR1
6A
LINE RESISTOR
OR1
LAMP
SIGNAL CUT-OFF SW
2A
S1
S-
2A
S2
S-
N.C.
COM
N.O.
AUX OR1
BELLS
1+
3
4
5
6
2-

LOCAL SYSTEM (EDWARDS)

Figure 10. Local System

To restore the system after a fire signal has been sent, the following circuits will be involved: The zone circuit, the signal circuit, and the trouble circuit. If a fire has actuated the zone circuit, the detectors involved must be inspected and, in some cases, replaced. This is particularly true of some fixed temperature detectors that have a fusible alloy link. Once the detectors have been restored, the reset button on the control panel is pressed to deenergize the zone circuit and allow the contacts to return to their normal position. The signal cutoff switch should be moved to the signal position and the trouble buzzer switch should be returned to the buzzer position. The system should now be ready to resume its duty in a normal supervisory condition.

SUMMARY

The purpose of a fire alarm system is to notify building occupants to evacuate and summon organized assistance. Electrical fire alarm systems may be either coded, noncoded, manual, automatic, and sprinkler, or deluge. Fire detectors can be heat, smoke, or flame detectors or operate electrically or electronically.

QUESTIONS

1. What is the purpose of the PFR relay?

2. How are the alarm bells silenced?

3. What is the function of the buzzer?

4. What is the principle of operation of a temperature detector?

5. Name the three circuits mentioned in the study guide on fire alarm systems.

CORROSION CONTROL AND CATHODIC PROTECTION

OBJECTIVES

The purpose of this study guide is to help you recognize corrosion of metals and the procedures necessary for the protection of metallic structures.

INTRODUCTION

The Air Force is interested in eliminating the waste of materials and manpower caused by corrosion of metals.

If the entire Air Force were located at one installation, the corrosion problem would not be so difficult to control, but because the Air Force has worldwide commitments, corrosion becomes a greater problem.

Cathodic protection is the reduction or prevention of corrosion of a metal surface. This is accomplished by making the metallic structure the cathode of a corrosive cell. Two types of protection in general use are the galvanic anode and the impressed current methods.

INFORMATION

THEORY OF CORROSION

Man has had corrosion problems to contend with ever since he started making items out of metal. Some metals, like iron, will corrode. Other metals, such as gold and silver, will not corrode. It has only been in this century that definite steps have been taken to prevent corrosion. The theory accepted today is that corrosion is basically electrochemical in nature.

Corrosion is defined as the gradual destruction of metal by electrochemical reaction with its environment.

Metals tend to return to their natural state. An example, iron returns to iron oxide. The factors necessary for corrosion are an anode, cathode, electrolyte, and a conductor. Ions flow from the anodic area through the electrolyte towards the cathodic area. See figure 11. Tiny pieces of metal make up the ions. Leaving the anodic area, metallic ions combine with negative ions and become oxides or rust. Thus corrosion is in progress. The tendency of a metal to corrode depends upon the potential between the metal and its ions in solution.

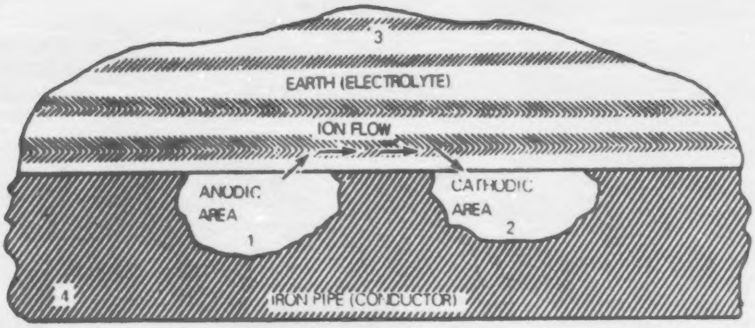


Figure 11. Simplified Corrosion Cell Showing Conditions Which Must Exist for Electrochemical Corrosion

Potential is determined by the type of metal and its ions in the solution.

TERMS USED IN CORROSION

The following terms are useful in understanding corrosion:

Anode - The electrode of an electrolytic cell at which oxidation occurs. In corrosion, it is usually the electrode from which the electrons flow to an external circuit.

Cathode - The electrode of an electrolytic cell, soil or the area that is not attacked, and is the electrode to which electrons flow from an external circuit.

Corrosion - The gradual destruction of a metal by chemical or electrochemical reaction with its environment.

Electrolyte - A chemical substance or mixture, soil or liquid, containing ions which migrate in an electrical field.

Electron - A fundamental particle carrying a negative electric charge. It is the fundamental carrier of electric current.

Ion - An electrically charged particle, in which the charge is due to the gain or loss of one or more electrons.

FORMS OF CORROSION

There are three general forms of corrosion.

Uniform Etch Corrosion

The surface effect produced by most direct chemical attacks. As an example, zinc, if exposed to hydrochloric acid, will corrode. On a polished surface this type of corrosion is first seen as a general dulling of the surface. If such corrosion is allowed to continue, the surface becomes rough and possibly frosted in appearance.

Localized Corrosion

Localized corrosion is caused by local action or local cells. A local cell is set when there is a difference of potential between areas on a metallic surface that is in an electrolyte. Localized corrosion may be in the form of pitting, cavitation, or erosion. Cavitation and erosion are started by mechanical forces. The sudden collapse of air bubbles between a metal surface and a liquid under pressure will cause the water to strike the surface of the metal with sufficient force to knock some metal off the surface. The holes left by this action will have sharp edges as if they had been chiseled out. Erosion is usually caused by the abrasive effect of liquids moving over the surface of a metal. Water has an abrasive effect and if it is moving fast enough, it will erode the metal. If the fluid should have sand or similar abrasive material in it, the sand will add to the erosion. Metal that has been eroded will look similar to soil that has been eroded. If an electric current passes from a piece of metal into a solution, it will take some of the metal with it, leaving a vacancy or pit in the surface of the metal. If the current leaves the metal equally over a large area, the corrosion will look similar to the corrosion caused by direct chemical attack. But if the current leaves only from spots on the metal, the metal will have spots of corrosion on it. Figure 12 shows some examples of corrosion that will leave pits in the metal surface.

Compositional Corrosion

Compositional corrosion is caused by dissimilar metals in contact with each other.

Brass is an alloy consisting mostly of copper and zinc. If brass is exposed to electrochemical corrosion, since the zinc is higher up on the galvanic series the zinc will be dissolved out of the alloy first, leaving the copper. The more common use of brass is in the manufacture of valves and similar pipe fittings. Since these brass fittings are usually joined to either iron or copper pipe, this type of corrosion can occur quite often and can be a great problem. Figure 12 shows a diagram of how this form of corrosion can occur. Cast iron is an alloy made of iron and carbon. The carbon is in the form of graphite. If cast iron is exposed to electromechanical corrosion, the iron will dissolve out and leave the graphite. It occurs quite often on cast-iron pipe. As often happens with underground pipe, most of the iron may dissolve out, leaving a graphite pipe. The graphite pipe may last for many years if it is not subject to any mechanical forces or sudden pressures.

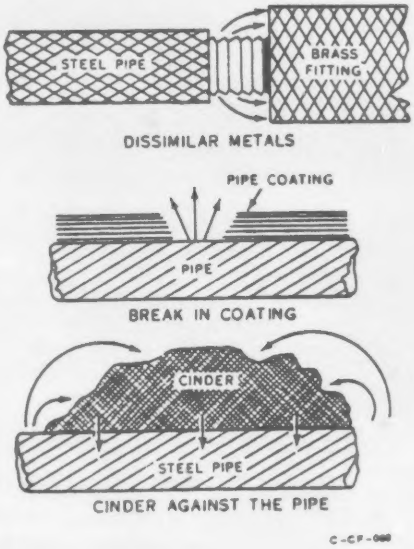


Figure 12. Examples of Corrosion

METHODS OF CONTROLLING CORROSION

In order to control corrosion, the electrochemical circuit must be broken. This may be accomplished by applying a coating of paint or plating with metallic surface. This will prevent the metallic surface from coming in contact with its corrosion environment. Another method to control corrosion is to introduce a countercurrent flow which will prevent current from leaving the metallic surface anodic areas. There are two methods used to provide this countercurrent flow, galvanic anode and impressed current.

Galvanic Anode Method

To control corrosion by the galvanic method, a metal anode higher in the electromotive force series and more negative than the metal to be protected must be electrically connected.

When magnesium and iron are connected, the more negative metal (magnesium), becomes the anode, and the metal to be protected (iron) becomes the cathode. Thus, a cathodic protection system is formed. Current leaves the anode as it corrodes and passes through the electrolyte (soil or water) to the cathode. If more current from the anode enters the protected metal preventing current from leaving it, corrosion will stop. See figures 13 and 14 for examples of cathodic protection by Galvanic (Sacrificial) Anode systems.

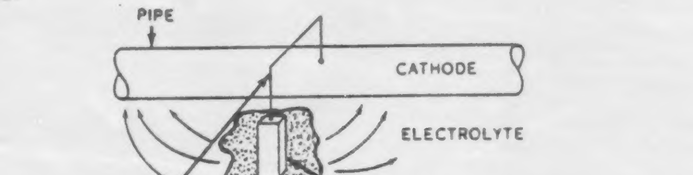

PIPE
CATHODE
ELECTROLYTE
EXTERNAL CIRCUIT
ZINC OR MAGNESIUM ANODE WITH PREPARED BACKFILL
PIPE
CATHODE
MAGNESIUM RIBBON ANODE
Cathode
Anode
Cathode
Cathode
Anode
Cathode
Tank Corroding
Magnesium Rod (Anode)
Tank Protected

Figure 13. Cathodic Protection by the Sacrificial Anode Method

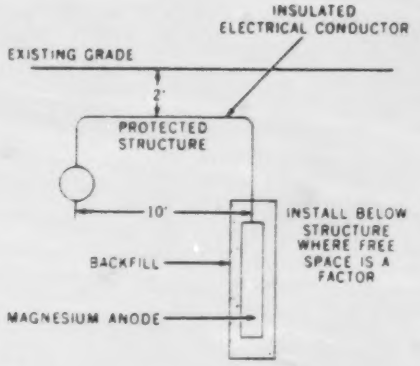

INSULATED ELECTRICAL CONDUCTOR
EXISTING GRADE
2'
PROTECTED STRUCTURE
10'
INSTALL BELOW STRUCTURE WHERE FREE SPACE IS A FACTOR
BACKFILL
MAGNESIUM ANODE

Figure 14. Typical Sacrificial Anode Installation

Advantages of Galvanic Anode System

The chief advantages of the galvanic or sacrificial anode system are:

1. No external power source is needed.
2. No regulation is needed.
3. Simplicity of installation.
4. Dangers from cathodic interference is minimized.
5. Maintenance is small over the anode life.

Disadvantages of the Galvanic Anode System

The chief disadvantages are:

1. Current output is limited.
2. Large numbers of anodes are usually required to protect bare structures.

Galvanic anode systems are preferred where areas to be protected are small. They are also preferred in hazardous locations, and on well-coated lines of pipe.

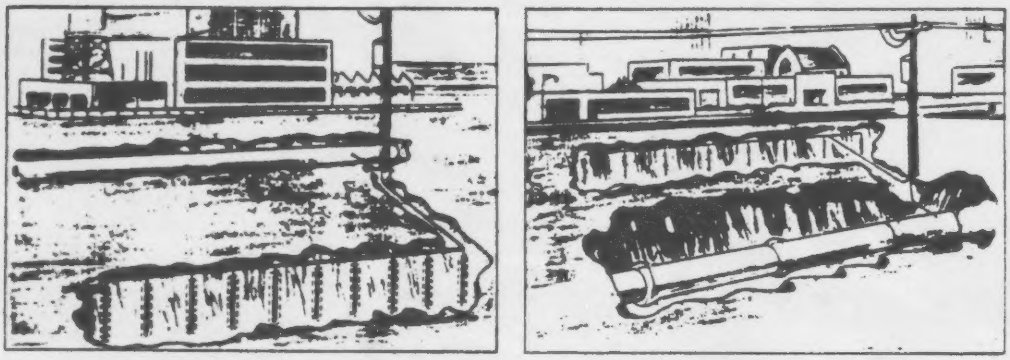
The major components of a galvanic anode system are cathode, anode, test stations, electrolyte, and backfill.

Impressed Current Method

An impressed current system normally consists of a source of dc power obtained from a rectifier set, an anode, cathode, test stations, electrolyte, and backfill. Current is forced from the source of power through the ground bed (anodes), the electrolyte, and to the structure to be protected (cathode). See figures 15 A, B, C, and D.

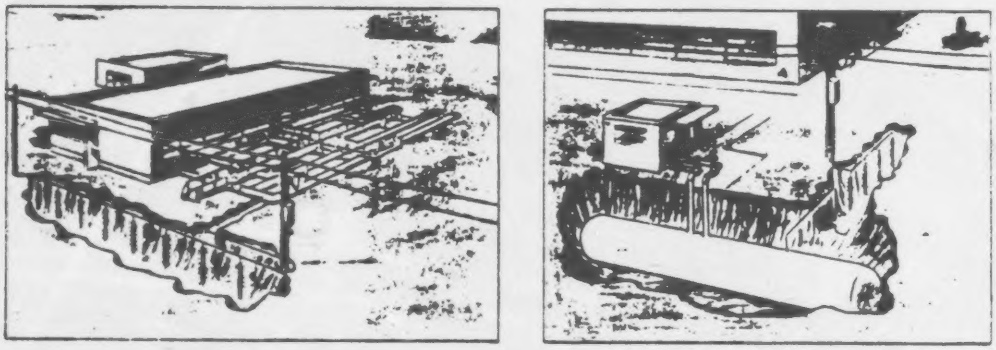
Anodes used in impressed current systems are inactive materials. They normally do not corrode until current is impressed and then only a small amount is lost over a period of years. The anodes are installed in a ground bed of soil or water. The two most common anodic materials used are graphite and high silicon cast iron. Scrap iron and aluminum is sometimes used. A closeup view of a graphite anode is shown in figure 16.

In the galvanic anode and impressed current systems, the current generated by both methods "buck out" the corrosion currents which occur when metal ions go into gaseous solution.



A Protection of Steel Pipe

B Protection of Cast-Iron Pipe



C Protect Line Booster Stations

D Protect Large Industrial Storage Tanks

Figure 15. Impressed Current Methods

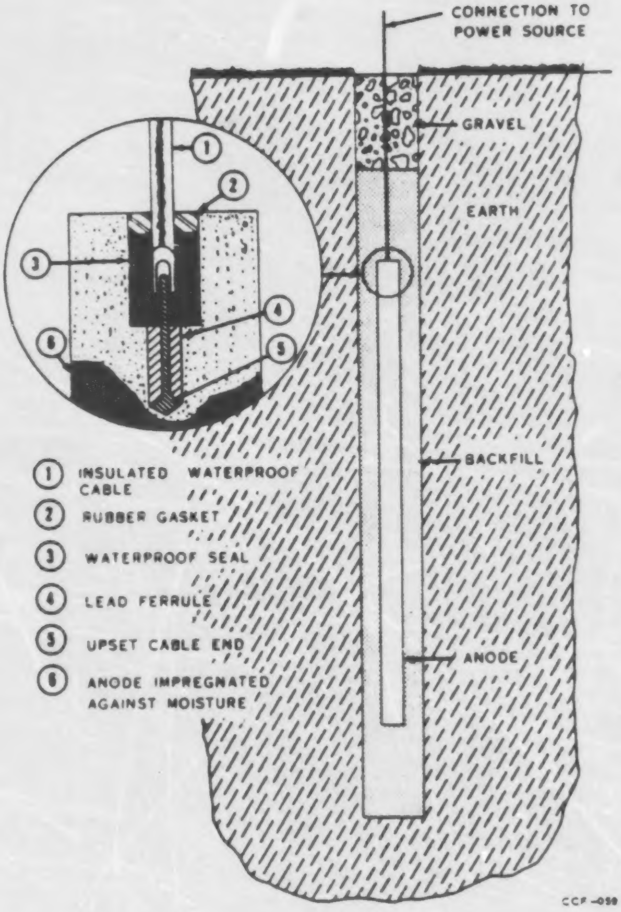

CONNECTION TO POWER SOURCE
GRAVEL
EARTH
BACKFILL
ANODE
1
2
3
4
5
6
① INSULATED WATERPROOF CABLE
② RUBBER GASKET
③ WATERPROOF SEAL
④ LEAD FERRULE
⑤ UPSET CABLE END
⑥ ANODE IMPREGNATED AGAINST MOISTURE
CCF-098

Figure 16. Graphite Anode Installed in Earth

An impressed current anode system, using graphite anodes, is shown in figure 17 Notice that the negative lead of the rectifier is connected to the structure or tank. The positive lead of the rectifier connects to the graphite anodes in backfill. Graphite anodes are very brittle and are subject to damage in handling and installing.

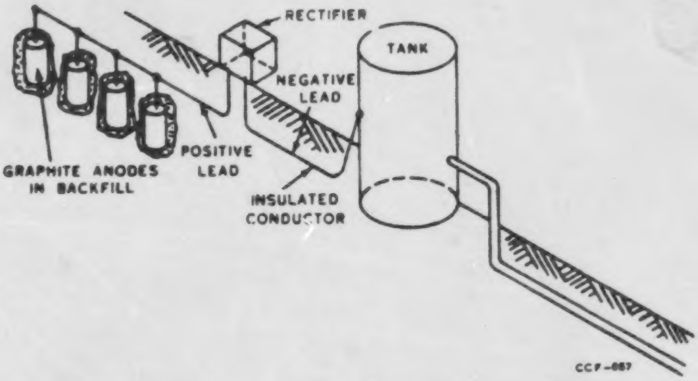


Figure 17. Impressed Current Anode System Using Graphite Anodes

Coke breeze backfill is used with graphite anodes for the purpose of establishing a lower resistance bond between the soil and the ground bed. Coke is a good conductor. When the graphite anode is installed in coke breeze, the coke breeze in effect becomes the anode. This backfill is about 77 percent carbon, 15 percent moisture, 4 percent sulphur, 1 percent ash, and the remainder is water.

Backfill lowers the anode-to-soil resistance and permits use of greater current density. The life of the anode is extended when coke breeze backfill is used by approximately ten to fifteen years.

Another material used for impressed current system anodes is high silicon cast iron. This anode is also very brittle. By composition it contains a minimum of 14.35 percent silicon, a maximum of 0.85 percent carbon, and 0.65 percent manganese. The remainder is iron. For high-chloride and high-temperature operation, 3 percent molybdenum may be added. Sizes of anodes range from 4 to 5 pounds for flexible assemblies and from 14 to 115 pounds for rigid types. Sizes above 55 pounds are used only in salt water.

Aluminum is used with impressed current systems to protect the interior of water storage tanks. Aluminum anodes are available in the form of wire, rod, and bar with sizes ranging from 1/16 to 8 inches in diameter. The commonly used diameter size rods are 1/2," 3/4," 1," 1 1/2," and 2."

Aluminum has the advantage of low initial cost and lightness of weight. Commercial anodes are only 75 percent efficient. They are consumed at the rate of 9 lbs per ampere year. This high consumption rate is undesirable, however, the corrosion products from aluminum do not contaminate potable water. The installation of these anodes is shown in figure 18.

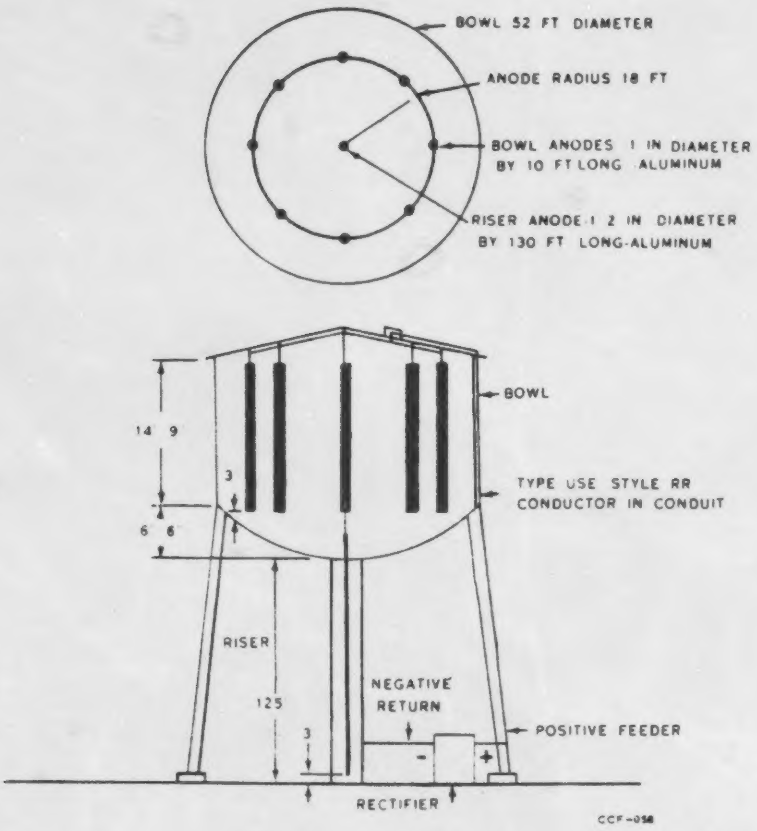

BOWL 52 FT DIAMETER
ANODE RADIUS 18 FT
BOWL ANODES 1 IN DIAMETER BY 10 FT LONG ALUMINUM
RISER ANODE 1 2 IN DIAMETER BY 130 FT LONG-ALUMINUM
BOWL
TYPE USE STYLE RR CONDUCTOR IN CONDUIT
14 9
3
6 6
RISER
125
3
NEGATIVE RETURN
POSITIVE FEEDER
-
+
RECTIFIER
CCF-058

Figure 18. Impressed Current Cathodic Protection System for 75,000-Gallon Elevated Water Tank Using Aluminum Anodes

Current Sources

The transformer-rectifier set shown in figure 19 is the principally used source of power for impressed current systems. Commercial 60-cycle 110-volt ac is frequently the input power. The transformer steps the ac down and connected to the secondary are selenium stacks in a full-wave bridge connection. The negative terminal of the rectifier is connected to the structure which is being protected. The positive terminal of the rectifier is connected to the impressed current anode bed.

The rectifier normally contains coarse taps and fine taps for adjusting the output voltage. Once these settings are made to adjust the output voltage, they are seldom disturbed unless a careful check is first made of the system. A voltmeter is provided for convenience on the inside panel of the rectifier for reading output dc voltage. An ammeter is similarly used to determine the dc flow in the output circuit. The purpose of the rectifier is to convert alternating current to direct current for use in the impressed current method of cathodic protection.

Rectifiers for cathodic protection use are available for ac voltages of 115, 230, or 460 volts, either single-phase or three-phase. Direct current voltages from 6 volts to 125 volts of 6 amperes to 200 amperes are common.

Selenium-iron stacks are commonly used for the rectifier. These stacks may be air-cooled or oil-immersed. Air-cooled stacks are subject to fouling of the air screens by dirt, dust, and insects. Oil-immersed stacks are free from these faults and are necessary in hazardous locations. Where high ambient temperatures, high humidity conditions, corrosive atmospheres, and wind or dust are present, totally oil-immersed rectifiers are preferred.

Silicon diodes have limited application in cathodic protection because they are susceptible to overload current or voltage surges. Silicon cells are lighter and show less drop in efficiency in use under controlled conditions.

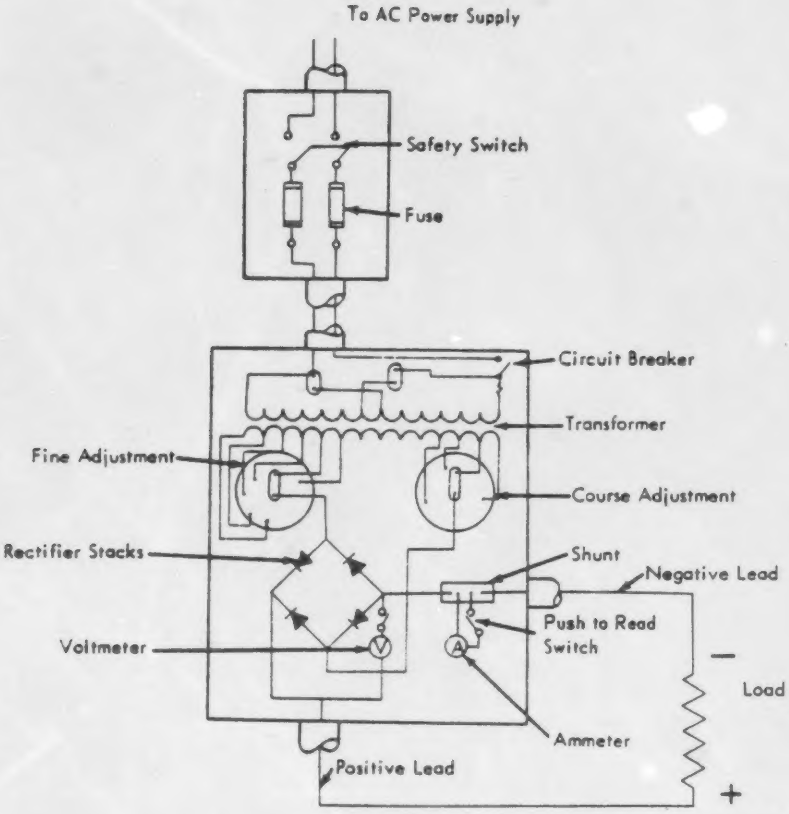
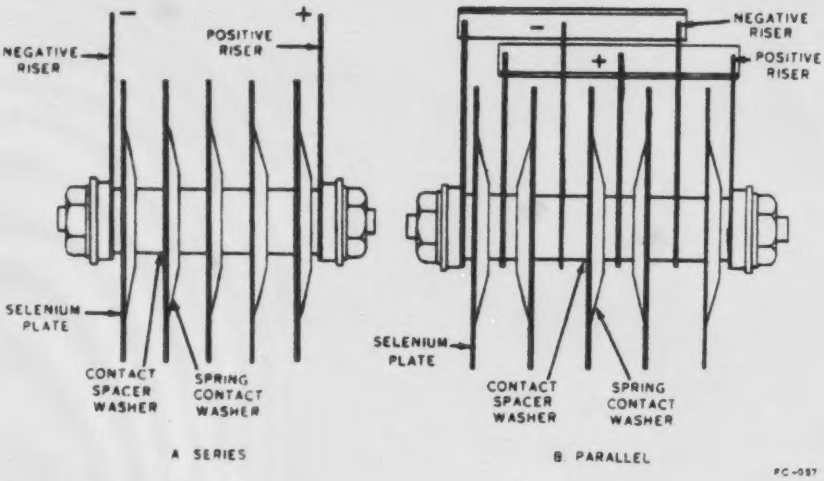

To AC Power Supply
Safety Switch
Fuse
Circuit Breaker
Transformer
Fine Adjustment
Course Adjustment
Rectifier Stacks
Shunt
Negative Lead
Push to Read Switch
Voltmeter
V
A
−
Load
Ammeter
Positive Lead
+

Figure 19. Wiring Diagram for 230-Volt, Single-Phase, Full-Wave, Bridge-Type Rectifier

Selenium stacks are illustrated in figures 20a and 20b in both series and parallel connections. Parallel connection is used to increase current available. Series connection is used to increase voltage.



−
+
NEGATIVE RISER
POSITIVE RISER
SELENIUM PLATE
CONTACT SPACER WASHER
SPRING CONTACT WASHER
A SERIES
−
+
NEGATIVE RISER
POSITIVE RISER
SELENIUM PLATE
CONTACT SPACER WASHER
SPRING CONTACT WASHER
B PARALLEL
FC-097

Figure 20. Selenium Rectifier Stack

Other sources of dc are sometimes used with impressed current systems. These are windmill-driven generators, motor-generator sets, engine-driven generators, or storage batteries. A welding rig can also furnish dc power for preliminary survey use.

SUMMARY

Corrosion is a universal problem with the Air Force. Man has had to contend with corrosion problems ever since he started using metals. There are three types of corrosion. These are uniform, localized, and composition. The theory today is that corrosion is caused by electrochemical means. Corrosion factors can be divided into two groups, those associated mainly with the metal and those associated with the environment. Most electrolytes themselves do not cause corrosion; however, they may carry the agents that do cause corrosion.

The two methods of cathodic protection are the sacrificial or galvanic anode method and the impressed current method. Both methods may be applied to structures aboveground, underground, and under water if the structure is in contact with an electrolyte. The electrolytes in cathodic protection are usually soil or water.

The two metals commonly used to protect steel structures are magnesium and zinc. Magnesium anodes usually are prepackaged in backfill. The chief advantage of the galvanic anode system is fairly uniform current distribution. Its chief disadvantages are low driving potential and small current output. The chief use of the galvanic anode system is in small installations.

The impressed current method of protection is used where the current demands are larger and the driving potential must be greater. Two commonly used anodes in the impressed current system are graphite and high-silicon cast iron. The graphite anode is used with coke-breeze backfill which, in effect, becomes the anode and extends its useful life. The source of power in the impressed current system is a rectifier. The selenium stacks are used in a full-wave, bridge-type connection to change ac to dc. Silicon is sometimes used in place of selenium.

Cathodic protecton "bucks out" corrosion currents which occur when metal ions at the anode go into gaseous solution. The bucking current comes from either galvanic anodes or impressed current.

QUESTIONS

1. Why is the Air Force interested in the corrosion problems?
2. How long has man been having corrosion problems?
3. How can electric current cause corrosion of metal?
4. Describe the methods used to cathodically protect the interior of a large water storage tank.
5. Draw a galvanic anode system, using five anodes to protect a pipeline.
6. Draw an impressed current system used to protect the bottom of a fuel storage tank if the tank rests on the ground.
7. Explain the purpose of backfill.
8. Compare the use of graphite and high-grade silicon cast iron in ground beds.
9. Why are aluminum anodes used mostly in water storage tanks?
10. Draw the schematic diagram for a rectifier used in the impressed current system.
11. Why is zinc used in place of magnesium for some galvanic anode systems?
12. Tell why selenium stacks are more commonly used in rectifiers than other materials.

WORKBOOKS

3ABR54230-1-V-1 thru 3

Technical Training

Electrician

CONTROLS AND ALARM SYSTEMS

August 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

Designed For ATC Course Use

DO NOT USE ON THE JOB

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2	Fire Alarm System	5
3	Cathodic Protection and Corrosion	7

This supersedes WBs 3ABR54230-1-V-1 thru 4, July 1973
(Copies of the superseded publication may be used until the supply is exhausted.)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-V-1
August 1975

INTRUSION ALARM SYSTEMS

OBJECTIVE

Upon completion of the exercise in this workbook, you will be familiar with the terms and definitions of the intrusion alarm circuits.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-V-1	1/student

PROCEDURE

INSTRUCTIONS

Project 1

1. Match the following terms and definitions by inserting the correct letter in the appropriate slot.

   a. B. A. Contact
   b. Drop or B. A. Drop
   c. Ground Alarm (Ground Drop)
   d. Supervised
   e. Combination Break and Ground Alarm (Double Drop)
   f. Annunciation
   g. Break Alarm (Break Drop)

   ( ) 1. An alarm created by an increased in line current to 30 MA.
   ( ) 2. The annunciating device used on the alarm switchboard.
   ( ) 3. If an alarm will result when the wire is broken or grounded or both.
   ( ) 4. An alarm created first by a decrease in line current below 9 MA and then an increase in line current to 30 MA.
   ( ) 5. Any device that is so placed as to cause an alarm when actuated.
   ( ) 6. An alarm caused by a decrease in line current below 9 MA.
   ( ) 7. Visual and audible signal indications received at the guardhouse.

2. Using the schematic in figure 1 and 2 (a) trace over the night supervisory circuit with a red color pencil, (b) trace the day supervisory circuit with a blue pencil, (c) and trace the alarm circuit with a green color pencil.

Project 2

3. In the spaces below, write in the nomenclature of the items identified in figure 1 by corresponding numbers.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________

Project 3

1. Using the trainer, figure 1 of workbook and meter, locate and correct any trouble found in the system.

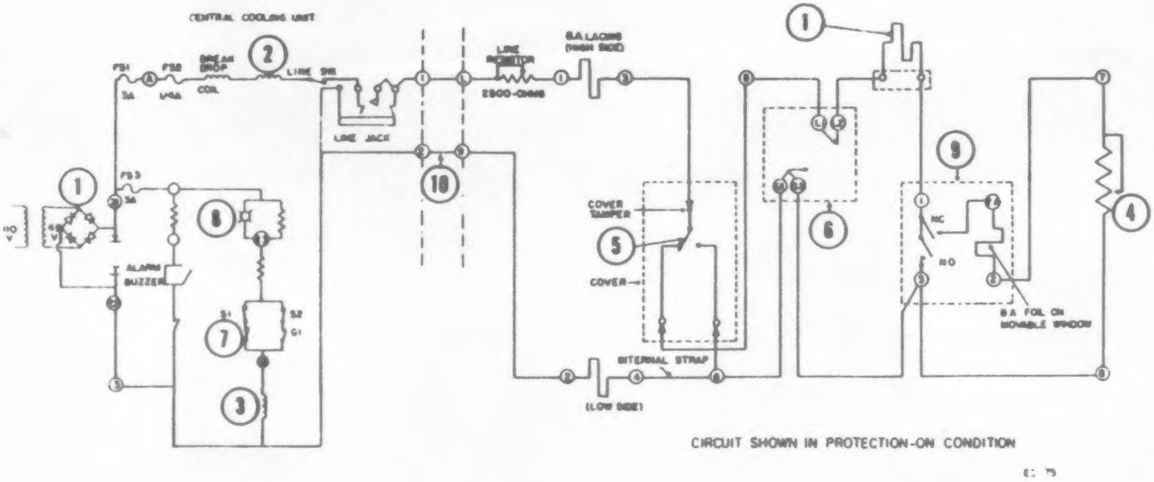
CENTRAL COOLING UNIT
FS1
3A
FS2
1/4A
BREAK DROP
COIL
LINE SW.
LINE JACK
LINE RESISTOR
2500-OHMS
B.A. LACING (HIGH SIDE)
(LOW SIDE)
INTERNAL STRAP
FS3
3A
110 V
ALARM BUZZER
S1
S2
G1
COVER TAMPER
COVER
NC
NO
B.A. FOIL ON MOVABLE WINDOW
1
2
3
4
5
6
7
8
9
10
CIRCUIT SHOWN IN PROTECTION-ON CONDITION

Figure 1. Schematic Wiring Diagram of Central and Local Control Units

Project 4

1. Using the trainer, figure 2 of workbook and meter, locate and correct any trouble found in the system.

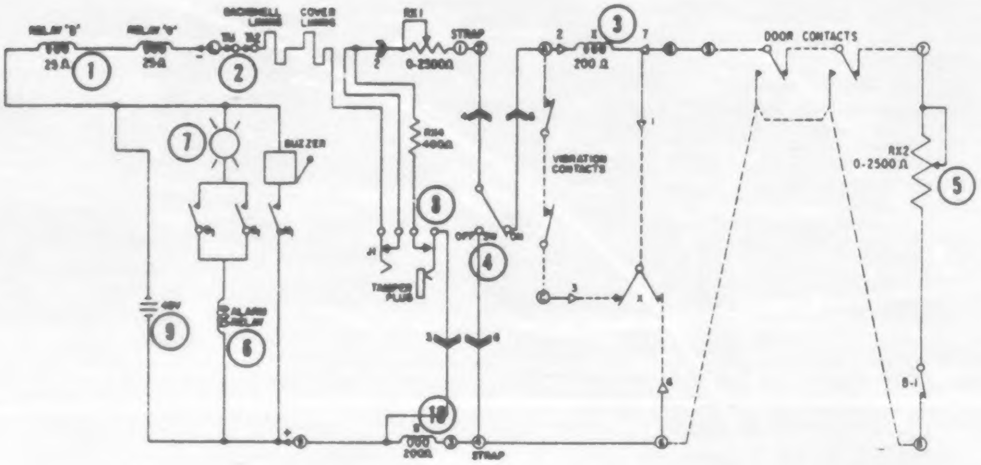
RELAY "B"
RELAY "A"
25 Ω
25Ω
1
2
COVER LINING
RX1
0-2500Ω
STRAP
2
X
3
7
200 Ω
DOOR CONTACTS
7
BUZZER
RX4
400Ω
VIBRATION CONTACTS
1
RX2
0-2500 Ω
5
8
J1
TAMPER PLUG
OFF
ON
4
3
X
48V
9
ALARM RELAY
6
3
4
B-1
+
10
200Ω
STRAP

Figure 2. 5912-CL Local Unit

424

2. In the spaces below, write in the nomenclature of the items identified in figure 2. by corresponding numbers.

1.	______________	6.	______________
2.	______________	7.	______________
3.	______________	8.	______________
4.	______________	9.	______________
5.	______________	10.	______________

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-V-2
August 1975

FIRE ALARM SYSTEMS

OBJECTIVE

Upon completion of the exercise in this workbook you will be familiar with the components of the fire alarm system.

Project 1

INSTRUCTIONS

Using figure 1 in your workbook, identify the numerical components by matching the number with the name.

( ) a. Fire detectors

( ) b. Operating relay (ORI)

( ) c. Battery supply

( ) d. Power supply

( ) e. Power failure relay

( ) f. Trouble switch (Manual)

( ) g. Line resistor

Project 2

Using a meter, the fire alarm trainer, and figure 3, locate troubles inserted into trainer by the instructor. When trouble is located, notify instructor.

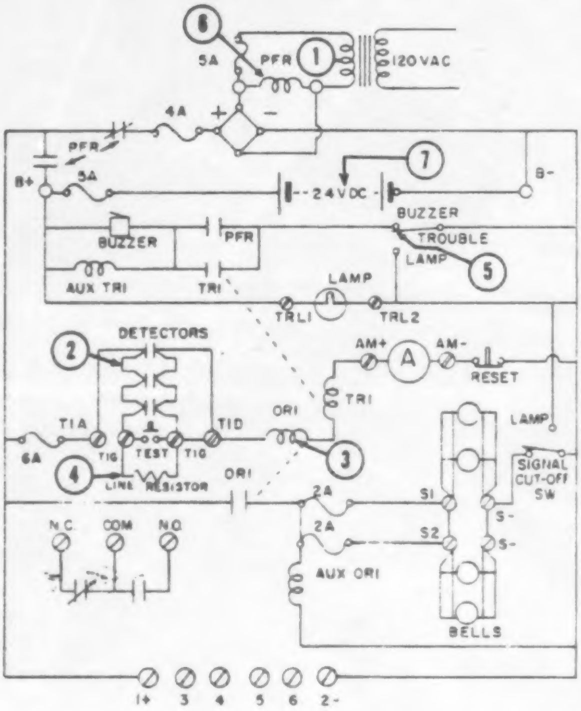
⑥
5A
PFR
①
120 VAC
4A
+
−
PFR
B+
5A
⑦
24 VDC
B-
BUZZER
TROUBLE
LAMP
⑤
BUZZER
PFR
AUX TRI
TRI
LAMP
TRL1
TRL2
DETECTORS
②
AM+
A
AM-
RESET
TRI
T1A
T1G
TEST
T1G
T1D
ORI
③
6A
④
LINE
RESISTOR
ORI
LAMP
SIGNAL CUT-OFF SW
2A
S1
S-
2A
S2
S-
N.C.
COM
N.O.
AUX ORI
BELLS
1+
3
4
5
6
2-

Figure 3. Local System

Project 3

Using the trainer, figure 3 of workbook and meter, locate and correct any trouble found in system.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-V-3
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CATHODIC PROTECTION AND CORROSION

OBJECTIVE

Upon completion of the exercises in this workbook, you will be familiar with corrosion and cathodic protection.

INSTRUCTIONS

Project 1

1. Using Study Guide 3ABR54230-1-V, complete the following sentences by writing in the blank spaces.

   a. The gradual destruction of a metal by electrochemical reaction with its environment is known as ______________________________

   b. An ____________ is an electrode in a corrosion cell which corrodes.

   c. A ____________ is the part of a corrosion cell that does not corrode.

   d. ____________ is a chemical substance or mixture containing ions.

   e. An electric current passes from the ____________ to the ____________ in corrosion.

   f. An ____________ is an electrical particle of metal as it passes from the anode through the electrolyte to the cathode.

   g. Metallic ions that enter the electrolyte leave the ______________ area.

   h. A metal's tendency to corrode depends upon the potential between the Metal and its ____________ in solution.

   i. The three types of corrosion are ____________, ____________, and ____________.

   j. The ground beds consist of anodes either submerged in ________ or ________.

   k. All ____________ structures are subject to corrosion.

2. Match the following terms with their definitions by inserting the correct letter in the appropriate slot.

a. Anode
b. Corrosion
c. Cathode
d. Ion
e. Electrolyte
f. Electron
g. Conductor

( ) 1. The gradual destruction of metal by electrochemical reaction with its environment.

( ) 2. The area that is not attacked.

( ) 3. An electrically charged particle, in which the charge is due to the gain or loss of electrons.

( ) 4. The area at which oxidation occurs.

( ) 5. A path for electron flow.

( ) 6. A mixture, usually liquid, containing ions that migrate in an electrical field.

( ) 7. A fundamental, negatively charged, electrical particle.

Project 2

1. Complete the following statements pertaining to cathodic protection.

a. List five advantages of a galvanic anode protection system.

(1) ____________________
(2) ____________________
(3) ____________________
(4) ____________________
(5) ____________________

b. List two disadvantages of a galvanic anode system.

(1) ____________________
(2) ____________________

c. List the major components of a galvanic anode system.

(1) ____________________
(2) ____________________
(3) ____________________
(4) ____________________

d. List the major components of an impressed current system.

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

(5) ______________________________

2. Complete the following sentences by writing in the blank spaces.

a. Cathodic protection is the reduction or prevention of ______________ a metal surface by making the metallic structure the ______________ of a corrosion cell.

b. The two methods of cathodic protection are ______________ and ______________.

c. The more active metal becomes the ______________ of a purposely established corrosion cell, and the metal to be protected becomes the ______________.

d. If the current from the ______________ is strong enough to prevent all current from leaving the anodic areas on the protected metal, corrosion will stop.

e. A direct current from an external source is forced to the ground bed through the electrolyte to the metal to be preserved in ______________. protection.

3. In the space below figures 4 and 5 enter the type of cathodic protection system.

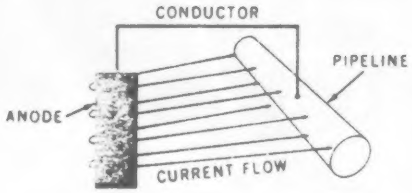

Figure 4. ______________

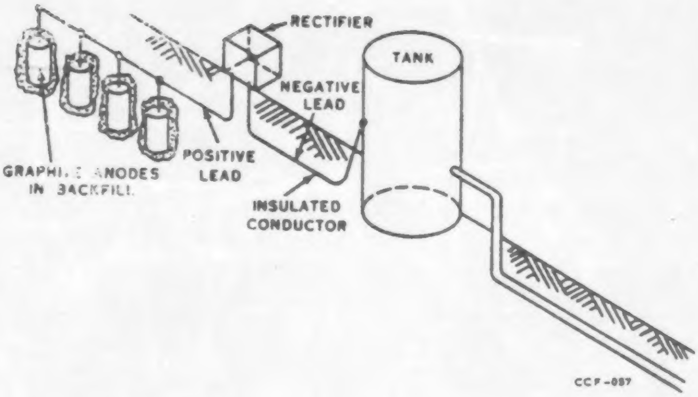
RECTIFIER
TANK
NEGATIVE LEAD
POSITIVE LEAD
GRAPHITE ANODES IN BACKFILL
INSULATED CONDUCTOR
CCF-087

Figure 5. ______________________________

REFERENCE

AFM 88-9, Corrosion Control, Chapter 4